



# De Revolutionibus Orbium Cælestium, Libri IV Nicolai Copernici Torinensis 1543

Six Books on the  
Revolutions of the  
Heavenly Spheres  
Nicholas Copernicus  
of Torun

Rocky Kolb  
Productions  
Presents

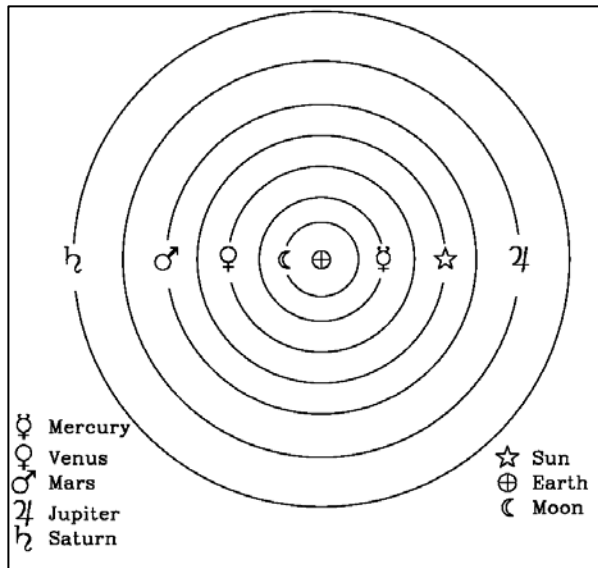
*The Dialogue Concerning the  
Two Chief World Systems*

★ April 11, 2006 ★

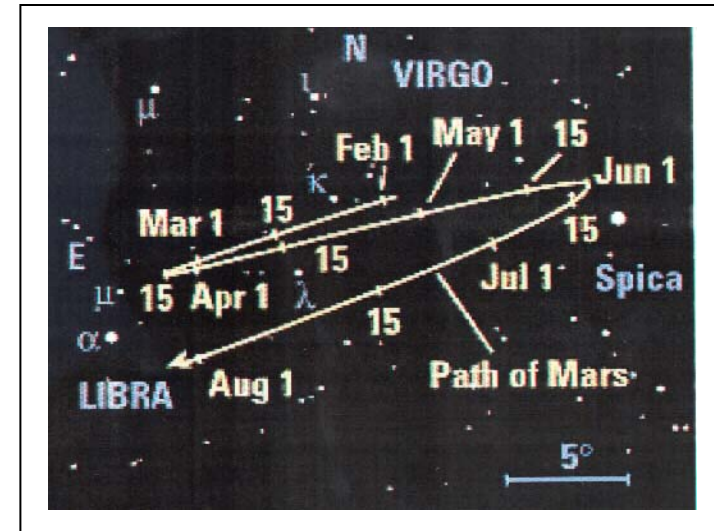
Salviati: Alexia Koelling  
Sagredo: Lija Bentley-Phillips  
Simplicio: Heath Blackerby



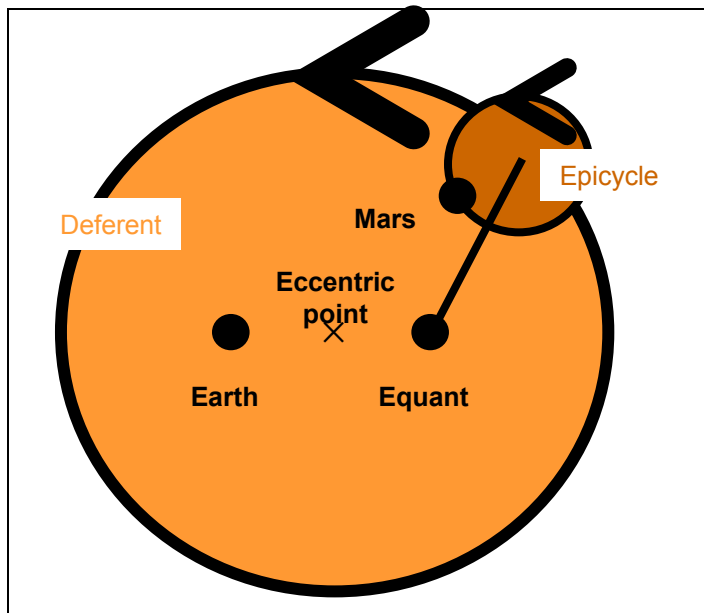
## Aristotle's universe



## Retrograde motion



## Epicycles



## The size of the universe

1. Geometry
2. Perfect logic
3. Large
4. Nested spheres
5. Smaller than actual

Object	Distance from Earth (in miles)		Radius (in miles)		Angular Size (in degrees)	
	Ptolemy	True	Ptolemy	True	Ptolemy	True
Earth	————	————	3,750	3,960	————	————
Moon	225,000	239,000	940	1,080	1/2	1/2
Sun	4,700,000	92,900,000	21,000	432,000	1/2	1/2

# Nested Spheres of Ptolemy



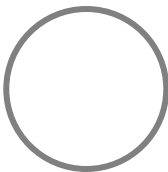
Earth



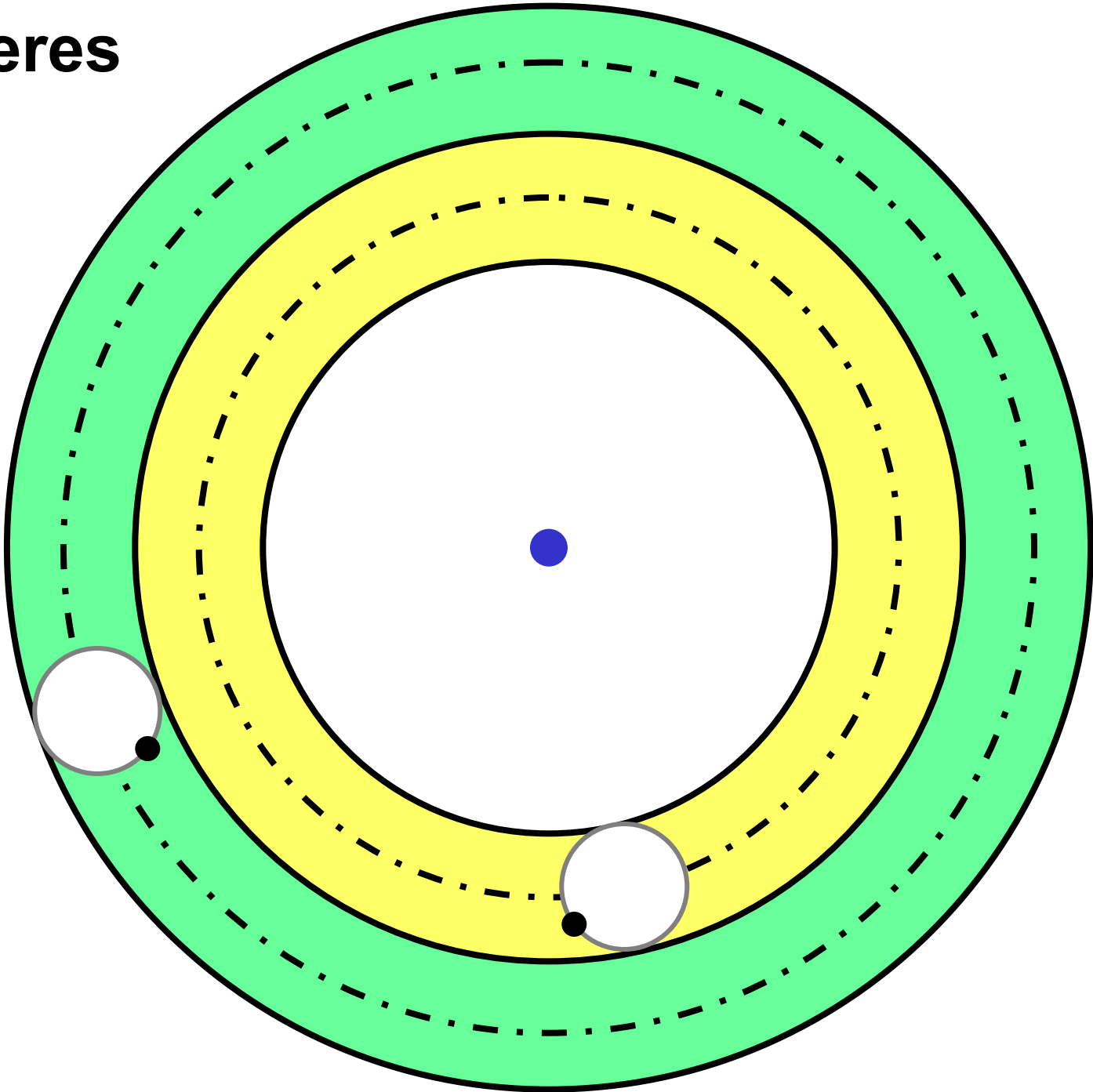
Planet

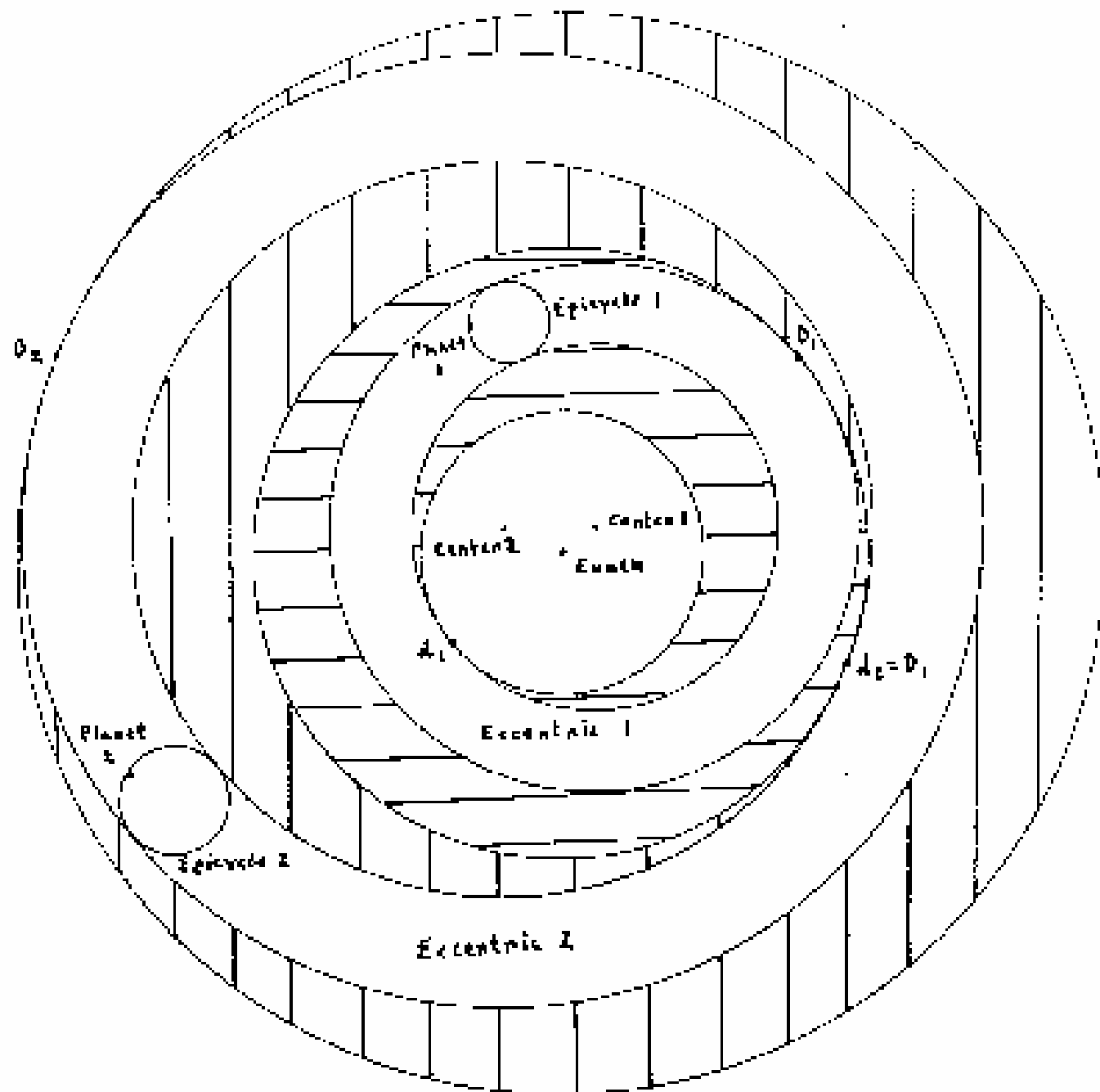


Deferent



Epicycle





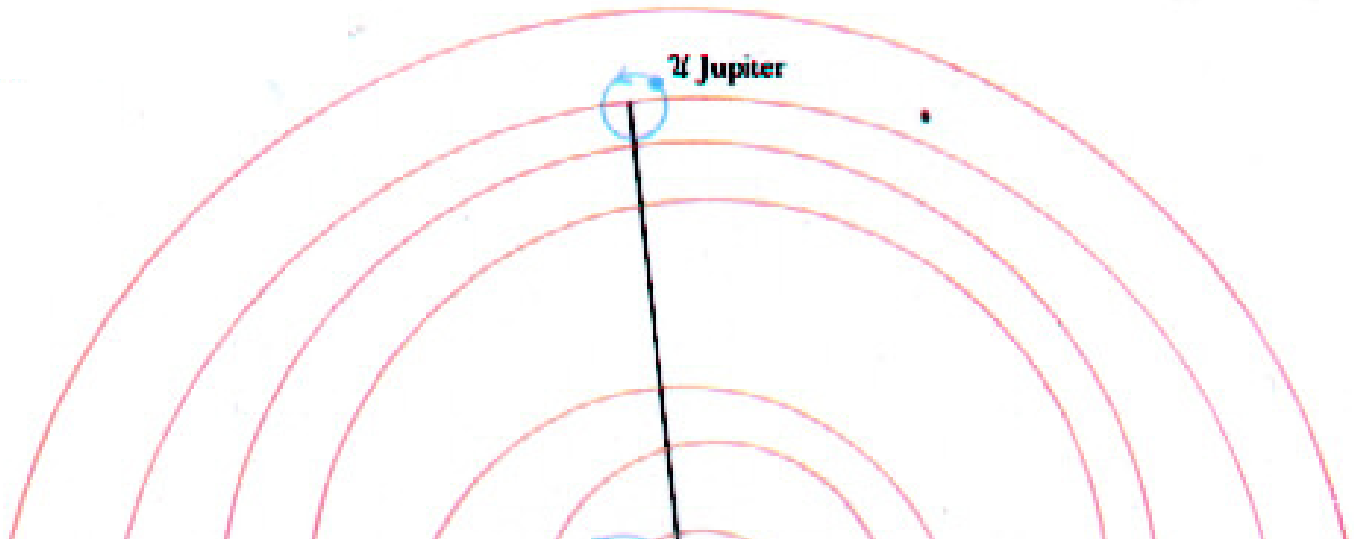
Planet	Distance from Earth (in millions of miles)		Angular Diameter (in minutes)		Actual Diameter (in miles)	
	Ptolemy	True	Ptolemy	True	Ptolemy	True
Earth	————	————	————	————	7,500	7,900
Mercury	0 .6	147	2	0.01	300	3,000
Venus	4	66	3	0.5	1,900	7,500
Mars	33	126	1.5	0.15	8,600	4,200
Jupiter	53	1,000	2.5	0.4	32,500	89,000
Saturn	74	2,000	1.7	0.2	32,000	75,000



**Raphael, School of Athens, in the Stanza della Segnatura**



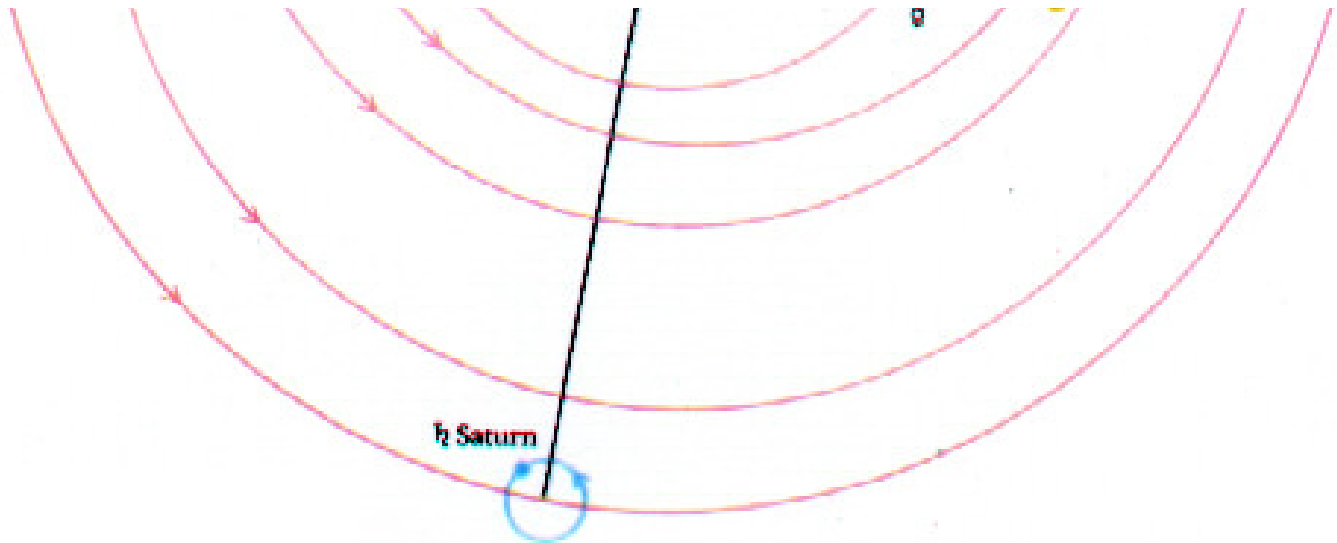
# System



If I had been present at creation, I would have suggested a simpler scheme.

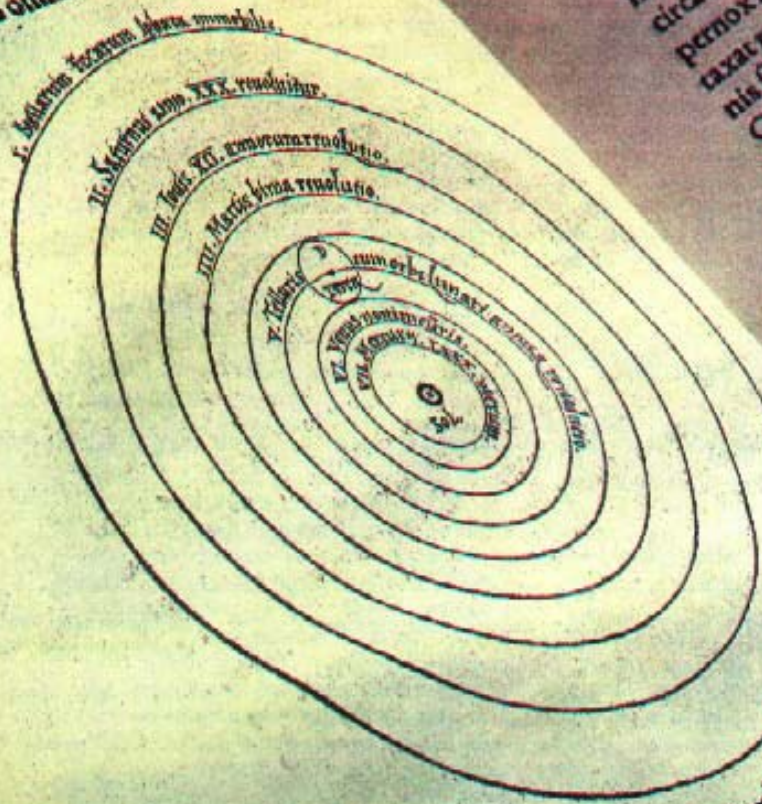
- Alfonse the Wise

# The Ptol



NICOLAI COPERNICI

o terram cum orbe lunari tanquam epicyclo considerat  
us. Quinto loco Venus nona mens rediit. Sexto  
loco Mercurius tenebatur, postea quinquaginta dierum spacio  
terra. In medio vero omnium relictus Sol. Quia enim in hoc



hac ordinatione ad  
monie nexum motus &  
do reperiri non potest. Hic  
ter contemplanti, cur maior in Me  
pareat, quam in Saturno in Me  
ior in Venere quam in Mar  
at in Saturno talis recipi  
Marte, & in Venere  
nus, Jupiter, & Mar  
circa eorum oculor  
pernox factus  
taxat rutilo  
nis stellar  
Quae  
tu.

pulcherrimo templo lampadem hanc  
neret, quam unde totum simul po  
nte quidam lucernam mi  
imiegithus infib  
fectio

**A**



**B**



**C**



**Nicholas Copernicus**  
**1473 - 1543**



Tobias Stimmer (1539-1584)  
astronomical clock  
of Strasbourg cathedral



*vera effigies exipsius autographo depicta*  
a true likeness from his own self portrait

Nicolaus Copernicus  
Torun town hall,



self portrait?

NICOLAI CO  
PERNICI TORINENSIS  
DE REVOLVTIONIBVS ORBIS  
um coelestium, Libri VI.

Habes in hoc opere iam recens nato, & ædito,  
studiose lector, Motus stellarum, tam fixarum,  
quàm erraticarum, cum ex ueteribus, tum etiam  
ex recentibus obseruationibus reſtitutos: & no-  
uis inſuper ac admirabilibus hypotheſibus or-  
natos. Habes etiam Tabulas expeditiſſimas, ex  
quibus eoſdem ad quoduis tempus quàm facilli-  
me calculare poteris. Igitur eme, lege, fruere.

Ἀγεμετρετοὶ μηδὲς εἰσὶτω.

Norimbergæ apud Ioh. Petreium,  
Anno M. D. XLIII.

Ageometretos  
medeis eisito.

Let no one  
untrained in  
geometry enter  
here.

Nicolaus Copernicus of Torun  
**Six Books on the Revolutions of the Heavenly Spheres**

Diligent reader, in this work, which has just been created and published, you have the motions of the fixed stars and planets, as these motions have been reconstituted on the basis of ancient as well as recent observations, and have moreover been embellished by new and marvelous hypotheses. You also have most convenient tables, from which you will be able to compute those motions with the utmost ease for any time whatever. Therefore buy, read, and enjoy (*eme, lege, fruere*).

Let no one untrained in geometry enter here.

Nuremberg  
Johannes Petreius  
1543

**N**ON dubito, quin eruditi quidam, uulgata iam de nouitate hypotheseon huius operis fama, quod terram mobilem, Solem uero in medio uniuersi immobilem constituit, uehementer sint offensi, putetque disciplinas liberales recte iam olim constitutas, turbari non oportere. Verum si rem exacte perpendere uolent, inuenient autorem huius operis, nihil quod reprehendi mereatur commississe. Est enim Astronomi proprium, historiam motuum coelestium diligenti & artificiosa obseruatione colligere. Deinde causas earundem, seu hypothesen, cum ueras assequi nulla ratione possit, qualescunque excogitare & confingere, quibus suppositis, iidem motus, ex Geometriæ principijs, tam in futurum, quam in præteritum recte possint calculari. Horum autem utrumque egregie præstitit hic artifex. Neque enim necesse est, eas hypothesen esse ueras, imò ne uerisimiles quidem, sed sufficit hoc uisum, si calculum obseruationibus congruentem exhibeant, nisi forte quis Geometriæ & Optices usque adeo sit ignarus, ut epicyclum Veneris pro uerisimili habeat, seu in causa esse credat, quod ea quadraginta partibus, & eo amplius, Sole interdum præcedat, interdum sequatur. Quis enim non uidet, hoc posito, necessario sequi, diametrum stellæ in *ωδργλ* plusquam quadruplo, corpus autem ipsum plusquam sedecuplo, maiora, quam in *αμγλ* apparere, cui tamen omnis æui experientia refragatur? Sunt & alia in hac disciplina non minus absurda, quæ in præsentiarum excutere, nihil est necesse. Satis enim patet, apparentium inæqualium motuum causas, hanc artē penitus & simpliciter ignorare. Et si quas fingendo excogitat, ut certe quamplurimas excogitat, nequaquam tamen in hoc excogitat, ut ita esse cuiquam persuadeat, sed tantum, ut calculum recte instituunt. Cum autem unus & eiusdem motus, uarie interdum hypothesen sese offerant (ut in motu Solis, eccentricitas, & epicyclum) Astronomus eam potissimum arripit, quæ compræhensu sit quam facillima, Philosophus fortasse, ueri similitudinem magis re-

gis requireret, neuter tamen quicquam certi compræhēdet, aut traderet, nisi diuinitus illi reuelatum fuerit. Sinamus igitur & has nouas hypothesen, inter ueteres, nihilo uerisimiliores innotescere præsertim cum admirabiles simul, & faciles sint, ingenitumque thesaurum, doctissimarum obseruationum secum aduehant. Neque quisquam, quod ad hypothesen attinet, quicquam certi ab Astronomia expectet, cum ipsa nihil tale præstare queat, ne si in alium usum conficta pro ueris arripiat, stultior ab hac disciplina discedat, quam accesserit. Vale.

NICOLAUS SCHONBERGIVS CARDINALIS Capuanus, Nicolao Copernico, S.



**C**VM mihi de uirtute tua, constanti omnium sermone ante annos aliquot allatum esset, ceptum tum maiorem in modum te animo complecti, atque gratulari etiam nostris hominibus, apud quos tanta gloria floreres. Intellexeram enim te non modo ueterum Mathematicorum inuenta egregie callere, sed etiam nouam Mundi rationem constituisse. Qua doceas terram moueri: Solem in medium mundi, adeoque medium locum obtinere: Coelum octauum immotum, atque fixum perpetuo manere: Lunam se unam cum inclusis suae sphaerae elementis, inter Martis & Veneris coelum sitam, annuarius cursu circum Solem conuertere. Atque de hac tota Astronomiae ratione commentarios à te confectos esse, ac erraticarum stellarum motus calculis subductos in tabulas te contulisse, maxima omnium cum admiratione. Quamobrem uir doctissime, nisi tibi molestus sum, te etiam atque etiam oro uehementer, ut hoc tuum inuentum studiosis comunices, & tuas de mundi sphaera lubricationes unam cum Tabulis, & si quid habes praeterea, quod ad eandem rem pertineat, primo quoque tempore ad me mittas. Dedi autem negotium Theodorico à Reden ut istis meis sumptibus omnia describantur, atque ad me transferantur. Quod si mihi morem in hac re gesseris, intelliges te cum homine nominis tui studioso, & tantae uirtuti satisfacere cupiente rem habuisse. Vale. Romae, Calend. Nouembris, anno M. D. XXXVI.

## To the Reader Concerning the Hypotheses of this Work.

There have already been widespread reports about the novel hypotheses of this work, which declares that the earth moves whereas the sun is at rest in the center of the universe ... it is the duty of an astronomer to compose the history of the celestial motions through careful and expert study. Then he must conceive and devise the causes of these motions or hypotheses about them. Since he cannot in any way attain to the true causes, he will adopt whatever suppositions enable the motions to be computed.... For these hypotheses need not be true nor even probable. On the contrary, if they provide a calculus consistent with the observations, that alone is enough.

So far as hypotheses are concerned, let no one expect any thing certain from astronomy, which cannot furnish it, lest he accept as the truth ideas conceived for another purpose, and depart from this study a greater fool than when he entered it.

AD SANCTIS-  
SIMVM DOMINVM PAV-  
LVM III. PONTIFICEM MAXIMUM,

Nicolai Copernici Præfatio in libros  
Reuolutionum.



ATIS equidem, Sanctissime Pater, æstimare possum, futurum esse, ut simul atq; quidam acceperint, me hisce meis libris, quos de Reuolutionibus sphaerarū mundi scripsi, terræ globo tribuere quosdam motus, statim me explodendum cum tali opinione clamitent. Neq; enim ita mihi mea placent, ut nō perpendam, quid alij de illis iudicaturi sint. Et quamuis sciam, hominis philosophi cogitationes esse remotas à iudicio vulgi, propterea quod illius studium sit ueritatem omnibus in rebus, quatenus id à Deo rationi humane permissum est, inquirere, tamen alienas prorsus à rectitudine opiniones fugiendas censeo. Itaq; cū mecum ipse cogitarem, quā absurdum *ἀπορροια* existimari essent illi, qui multorum seculorum iudicijs hanc opinionē confirmatam norūt, quod terra immobilis in medio cœli, tanquam centrum illius posita sit, si ego contra assererem terram moueri, diu mecum hæsi, an meos cōmentarios in eius motus demonstrationem conscriptos in lucem darem, an uero satius esset, Pythagoreorum & quorundam aliorum sequi exemplū, qui non per literas, sed per manus tradere soliti sunt mysteriā philosophiæ propinquis & amicis duntaxat. Sicut Lyfidis ad Hipparchum epistola testatur. Ac mihi quidem uidentur id fecisse: non ut quidam arbitrantur ex quadam inuidencia communicandarum doctrinarum, Sed ne res pulcherrimæ, & multo studio magnorum uirorum inuestigate, ab illis contemnerentur, quos aut piget ullis literis bonam operam impendere, nisi quæstuosis, aut si exhortationibus & exemplo aliorum ad liberale studium philosophiæ excitentur, tamen propter stupida

PRAEFATIO AVTHORIS.

stupiditatem ingenij inter philosophos, tanq; fuci inter apes uersantur. Cum igitur hæc mecum perpenderem, contemptus, qui mihi propter nouitatem & absurditatē opinionis metuentus erat, propemodum impulerat me, ut institutum opus prorsus intermitterem.

Verum amici me diu cunctantem atq; etiā reluctantem retraxerūt, inter quos primus fuit Nicolaus Schonbergius Cardinalis Capuanus, in omni genere doctrinarū celebris. Proximus illi uir mei amantissimus Tidemannus Gisius, episcopus Culmenensis, sacrarum ut est, & omnium bonarū literarum studiosissimus. Is etenim saepenumero me adhortatus est, & conuictijs interdum additis efflagitauit, ut librum hunc æderem, & in lucem tandem prodire sinerem, qui apud me pressus non in nonum annū solum, sed iam in quartum nouenniū, latitasset. Idem apud me egerunt alij non pauci uiri eminentissimi & doctissimi, adhortantes ut meam operam ad communem studio forum Mathematices utilitatem, propter conceptum metum, conferre non recularem diutius. Fore ut quanto absurdior plerisque nunc hæc mea doctrina de terræ motu uideretur, tanto plus admirationis atq; gratiæ habitura esset, postq; per æditionem cōmentariorum meorum caliginem absurditatis sublatā uiderent liquidissimis demonstrationibus. His igitur persuasoribus, eaq; spe adductus, tandem amicis permisi, ut æditionē operis, quam diu à me petissent, facerent.

At nō tam mirabitur fortasse Sanctitas tua, quod has meas lucubratiōes ædere in lucem ausus sim, posteaq; tantum operæ in illis elaborandis, mihi sumpsi, ut meas cogitationes de terræ motu etiam literis cōmittere non dubitauerim, sed quod magis ex me audire expectat, qui mihi in mentem uenerit, ut contra receptam opinionem Mathematicorum, ac propemodum contra communem sensum, ausus fuerim imaginari aliquē motum terræ. Itaq; nolo Sanctitatem tuā latere, me nihil aliud mouisse, ad cogitandum de alia ratione subducendorum motuum sphaerarum mundi, quā quod intellexi, Mathematicos sibi ipsis non constare in illis perquirendis. Primū enim usq; adeo incerti sunt de motu Solis & Lunæ, ut nec uertentis anni perpetuam

tuam magnitudinem demonstrare & observare possint. Deinde in constituendis motibus, cum illarum, tum aliarum quinque errantium stellarum, neque ipsidem principijs & assumptionibus, ac apparentium reuolutionum motuumque demonstrationibus, utuntur. Alij namque circulis homocentris solum, alij eccentricis & epicyclis, quibus tamen quaesita ad plenum non assequuntur. Nam qui homocentris confisi sunt, etsi motus alios quos diuersos ex eis componi posse demonstrauerint, nihil tamen certi, quod nimirum phaenomenis responderet, inde statuere potuerunt. Qui uero excogitauerunt eccentrica, etsi magna ex parte apparentes motus, congruentibus per ea numeris absoluisse uideantur: plerumque tamen interim admisserunt, quae primis principijs, de motus aequalitate, uidentur contrarietate. Rem quoque praecipuam, hoc est mundi formam, ac partium eius certam symmetriam non potuerunt inuenire, uel ex illis colligere. Sed accidit eis perinde, ac si quis e diuersis locis, manus, pedes, caput, aliaque membra, optime quidem, sed non unius corporis comparatione, depicta sumeret, nullatenus inuicem sibi respondentibus, ut monstrum potius quam homo ex illis componeretur. Itaque in processu demonstrationis, quam *μειζότερον* uocant, uel praeteriisse aliquid necessarium, uel alienum quid, & ad rem minime pertinens, admisisse inueniuntur. Id quod illis minime accidisset, si certa principia sequuti essent. Nam si assumptae illorum hypotheses non essent fallaces, omnia quae ex illis sequuntur, uerificarentur proculdubio. Obscura autem licet haec sint, quae nunc dico, tamen suo loco fient apertiora.

Hanc igitur incertitudinem Mathematicarum traditionum, de colligendis motibus sphaerarum orbis, cum diu mecum reuoluerem, coepit me tædere, quod nulla certior ratio motuum machinae mundi, qui propter nos, ab optimo & regularis, omnium opifice, conditus esset, philosophis constaret, qui alioqui rerum minutis, respectu eius orbis, tam exquisitè scrutarentur. Quare hanc mihi operam sumpsi, ut omnium philosophorum, quos habere possem, libros relegerem, indagaturus, an ne ullus unquam opinatus esset, alios esse

motus

motus sphaerarum mundi, quam illi ponerent, qui in scholis Mathematica profiterentur. Ac reperi quidem apud Ciceronem primum, Nicetum sensisse terram moueri. Postea & apud Plutarchum inueni quosdam alios in ea fuisse opinione, cuius uerba, ut sint omnibus obuia, placuit hic ascribere: *οἱ μὲν ἄλλοι μὲν τὴν γῆν, οὐλοχρος δὲ πυθαγόρης κύκλῳ περιφερεῖσθαι πρὸς τὸ πρὸ κατανκλῆς λαβῆς ὁμοιοπαῶς ἡλίῳ καὶ σελῶν. Ἡρακλείδης ὁ παντικός ἔστι φαντος ὁ πυθαγόρης κινῆσαι μὲν τὴν γῆν ἔμεινεν γὰρ μεταβατικῶς, τροχῷ δὲ πᾶσι τῶν σφαιρῶν ἐπὶ δυσμενῶν ὑπὲρ αἰατολάς, πρὸς τὸ ἴδιον αὐτῆς κινῆσθαι.*

Inde igitur occasionem nactus, coepi & ego de terrae mobilitate cogitare. Et quamuis absurda opinio uidebatur, tamen quia sciebam alijs ante me hanc concessam libertatem, ut quoslibet fingerent circulos ad demonstrandum phaenomena astrorum. Existimaui mihi quoque facile permitti, ut experirem, an posito terrae aliquo motu firmiores demonstrationes, quam illorum essent, inueniri in reuolutione orbium coelestium possent.

Atque ita ego positis motibus, quos terrae infra in opere tribuo, multa & longa observatione tandem reperi, quod si reliquorum syderum errantium motus, ad terrae circulationem conferantur, & supputentur pro cuiusque syderis reuolutione, non modo illorum phaenomena inde sequantur, sed & syderum atque orbium omnium ordines, magnitudines, & coelum ipsum ita connectat, ut in nulla sui parte possit transponi aliquid, sine reliquarum partium, ac totius uniuersitatis confusione. Proinde quoque & in progressu operis hunc sequutus sum ordinem ut in primo libro describam omnes positiones orbium, cum terrae, quos ei tribuo, motibus, ut is liber contineat communem quasi constitutionem uniuersi. In reliquis uero libris postea confero reliquorum syderum atque omnium orbium motus, cum terrae mobilitate, ut inde colligi possit, quatenus reliquorum syderum atque orbium motus & apparentiae saluari possint, si ad terrae motus conferantur. Neque dubito, quin ingeniosi atque docti Mathematici mihi astipulaturi sint, si quod haec

philosophia in primis exigit, nō obiter, sed penitus, ea quæ ad harum rerum demonstrationē à me in hoc opere, adferuntur, cognoscere atq; expēdere uoluerint. Vt uero pariter docti atq; indocti uiderent, me nullius omnino subterfugere iudiciū, malui tuæ Sanctitati, quàm cuiq; alteri has meas lucubrationes de dicare, propterea quod & in hoc remotiss. angulo terræ, in quo ego ago, ordinis dignitate, & literarum omniū atq; Mathematicæ etiam amore, eminentiss. habeatis, ut facile tua autoritate & iudicio calumniantium morsus reprimere possis, etsi in puerbio sit, non esse remedium aduersus tyrophantæ morsum.

Si fortasse erunt *μεινους λογοι*, qui cum omnium Mathematicum ignari sint, tamen de illis iudicium sibi sumunt, propter aliquem locum scripturæ, male ad suum propositum detortū, ausi fuerint meum hoc institutum reprehendere ac insectari: nil mihi moror, adeo ut etiam illorum iudicium tanq; temerarium contemnam. Non enim obscurum est Lactantium, celebrem alioqui scriptorem, sed Mathematicum parum, admodū pueriliter de forma terræ loqui, cum deridet eos, qui terræ globi formam habere prodiderunt. Itaq; nō debet mirum uideri studiosis, si qui tales nos etiam ridebunt. Mathemata mathematicis scribuntur, quibus & hi nostri labores, si me non fallit opinio, uidebuntur etiam Reipub. ecclesiasticæ conducere aliquid, cuius principatum tua Sanctitas nunc tenet. Nam non ita multo ante sub Leone x. cum in Concilio Lateranensi uertabatur quæstio de emendando Calendario Ecclesiastico, quæ cum indecisa hanc solummodo ob causam mansit, quod annorum & mensium magnitudines, atq; Solis & Lunæ motus nondum satis dimensi haberentur. Ex quo equidem tempore, his accuratius obseruandis, animum intendi, admonitus à præclariss. uiro D. Paulo episcopo Sempronienſi, qui tum isti negotio præerat. Quid autem præstiterim ea in re, tuæ Sanctitatis præcipue, atq; omnium aliorum doctorum Mathematicorum iudicio relinquo, & ne plura de utilitate operis promittere tuæ Sanctitati uidear, quàm præstare possim, nunc ad institutum transeo.

## INDEX EORVM

QVAE IN SINGVLIS CAPITIBVS, SEX  
librorum Nicolai Copernici, de reuolutionibus orbium  
coelestium, continentur.

## LIBER PRIMVS.

1. Quod mundus sit sphaericus.
2. Quod terra quoq; sphaerica sit.
3. Quomodo terra cum aqua unum globum perficiat.
4. Quod motus corporum coelestium sit aequalis ac circularis, perpetuus, uel ex circularibus compositus.
5. An terra competat motus circularis, & de loco eius.
6. De immensitate cœli ad magnitudinem terræ.
7. Cur antiqui arbitrati sint terram in medio mundi quiescere, tanq; centrum.
8. Solutio dictarum rationum, & earum insufficientia.
9. An terræ plures possint attribui motus, & de centro mundi.
10. De ordine coelestium orbium.
11. De triplici motu telluris demonstratio.
12. De magnitudine rectarum in circulo linearum.
13. De lateribus & angulis triangulorum planorum rectilineorum.
14. De triangulis sphaericis.

## LIBER SECVNDVS.

1. De circulis & eorum nominibus.
2. De obliquitate signiferi, & distātia tropicorū, & quomodo capiāt.
3. De circumferentijs & angulis secantium sese circuloꝝ, æquinoctialis, signiferi, & meridiani, e quibus est declinatio & ascensio recta, deq; eorum supputatione.
4. Quomodo etiā cuiuslibet syderis extra circulū, q̄ per mediū signorum est positi, cuius tamē latitudo cū lōgitudine cōstiterit, declinatio & ascensio recta pateat, & cū q̄ gradu signiferi cælū mediat.
5. De finitoris sectionibus.
6. Quæ sint umbrarum meridianarum differentia.
7. Maximus dies, latitudo ortus, & inclinatio sphaeræ, quomodo inuicem demonstrantur, & de reliquis dierum differentijs.
8. De horis & partibus diei & noctis.
9. De ascensione obliqua partium signiferi, & quemadmodum ad quemlibet gradum orientem, detur & is qui cælum mediat.
10. De angulo sectionis signiferi cum horizonte.
11. De usu harum tabularum.
12. De angulis & circumferentijs eorum, qui per polos horizontis fiunt ad eundem circulum signorum.



**Copernicus**

***“Mathemeta  
mathematicus  
scribuntur.”  
(Astronomy  
is for  
Astronomers.)***

**From the preface to  
*De Revolutionibus***

13. De ortu & occafu fiderum.  
14. De exquirendis ftellarum locis, ac fixarum canonica defcriptio.

## LIBER TERTIVS.

1. De æquinoctiorum folitiorumq; anticipatone.
2. Hiftoria obferuationum comprobantium inæqualem æquinoctiorum conuerfionumq; præceffionem.
3. Hypothefes, quibus æquinoctiorum obliquitatisq; figniferi, & æquinoctialis mutatio, demonftratur.
4. Quomodo motus reciprocos, fide librationis ex circularibus cõftet.
5. Inæqualitatis anticipantiũ æquinoctiorũ & obliquitatis demonftratio.
6. De æqualibus motib; præceffionis æquinoctiorũ & inclinatiois zodiaci.
7. Quæ fit maxima differentia inter æqualem apparentemq; præceffionem æquinoctiorum.
8. De particularibus ipforum motuum differentijs, & eorum Canonica expofitio.
9. De eorum, quæ circa præceffionem æquinoctiorum expofita funt, examinatione ac emendatione.
10. Quæ fit maxia differentia fectionum æquinoctialis & zodiaci.
11. De locis æqualiũ motuũ æquinoctiorũ, & anomaliz cõftituendis.
12. De præceffionis æquinoctij uerni, & obliquitatis fupputatione.
13. De anni folaris magnitudine & differentia.
14. De æqualibus medijsq; motibus reuolutionum centri terræ.
15. Protheoremata ad inæqualitatem motus folaris apparentis demonftrandam.
16. De apparente Solis inæqualitate.
17. Primæ ac annuæ Solaris inæqualitatis demonftratio cum ipfius particularibus differentijs.
18. De examinatione motus æqualis fecundum longitudinem.
19. De locis & principijs æquali motui Solis præfigendis.
20. De fecunda & duplici differentia, quæ circa Solem propter abfildum mutationem contingit.
21. Quanta fit fecunda Solaris inæqualitatis differentia.
22. Quomodo æqualis apogæi folaris motus, unâ cũ differẽte explicet.
23. De anomaliz Solis emendatioe, & de locis eius præfigendis.
24. Expofitio Canonica differentiarum æqualitatis & apparentiz.
25. De Solaris apparentiz fupputatione.
26. De Νυγμωδω, hoc eft diei naturalis differentia.

## LIBER QVARTVS.

1. Hypothefes circularum lunarium opinione prifcorum.
2. De earum affumptionum defectu.
3. Alia de motu Lunæ fententia.
4. De reuolutionibus Lunæ, & motibus eius particularibus.
5. Primæ inæqualitatis Lunæ, quæ in noua, plenaq; cõtingit demonftratio.

Eorum

6. Eorum quæ de æqualibus Lunæ motibus longitudinis anomaliz expofita funt comprobatio.
7. De locis longitudinis & anomaliz Lunaris.
8. De fecunda Lunæ differentia, & quam habeat rationem epicyclus primus ad fecundum.
9. De reliqua differentia, qua Luna à fuma abfide epicycli inæqualiter uidetur moueri.
10. Quomodo lunaris motus apparẽs ex datis æqualibus demonfret.
11. Expofitio Canonica pñthaphærefiũ, fide æquationũ Lunarum.
12. De Lunaribus curfus dinumeratione.
13. Quomodo motus latitudinis lunaris examinetur & demonftratur.
14. De locis anomaliz latitudinis Lunæ.
15. Inftrumenti parallatici conftructio.
16. De Lunæ commutationibus.
17. Lunaribus à terra diftantia, & quam habeant rationem in partibus, quibus quæ ex cẽtro terræ ad fupficiem eft una, demonftratio.
18. De diametro Lunæ umbræ terreftis, in loco tranfitus Lunæ.
19. Quomodo Solis & Lunæ à terra diftãtia, eorumq; diametri, ac umbræ in loco tranfitus Lunæ, & axis umbræ fimul demonfrentur.
20. De magnitudine horũ triũ fiderũ, Solis, Lunæ, & Terræ, ac inuicẽ.
21. De diametro Solis apparẽte & eius cõmutatiõib; (cõparatiõẽ).
22. De diametro Lunæ inæqualiter apparẽte & eius cõmutatiõibus.
23. Quæ fit ratio diuerfitatis umbræ terræ.
24. Expofitio Canonica particularium commutationum Solis & Lunæ in circulo qui per polos horizontis.
25. De numeratione parallaxis Solis & Lunæ.
26. Quomodo parallaxes longitudinis & latitudinis difcernuntur.
27. Confirmatio eorum, quæ circa Lunæ parallaxes funt expofita.
28. De Solis & Lunæ coniunctiõibus, oppofitiõibusq; medijs.
29. De ueris cõiunctiõibus & oppofitiõibus Solis & Lunæ pferutandis.
30. Quomodo cõiunctiões & oppofitiões Solis & Lunæ eclipticæ difcarnantur ab alijs.
31. Quantus fuerit Solis Lunæq; defectus.
32. Ad prænofcendum quantisper duraturus fit defectus.

## LIBER QVINTVS.

1. De reuolutionibus eorum, & medijs motibus.
2. Aequalitatis & apparẽtiz ipforũ fiderũ demonftratio, opinioe prifcorum.
3. Generalis demonftratio inæqualitatis apparẽtis ppter motũ terræ.
4. Quibus modis errantium motus proprii appareant inæquales.
5. Saturni motus demonftrationes.
6. De alijs tribus recentius obferuatis circa Saturnum acronychijs.
7. De motus Saturni examinatione.
8. De Saturni locis cõftituendis.
9. De Saturni commutationibus, quæ ab orbe terræ annuo proficiuntur, & quanta illius fit diftantia.
10. Iouis motus demonftrationes.

De alijs

11. De alijs tribus acronychijs Iouis recentius obseruatis.
12. Comprobatio æqualis motus Iouis.
13. Loca motus Iouis assignanda.
14. De Iouis commutationibus percipiendis, & eius altitudine pro ratione orbis reuolutionis terrenæ.
15. De stella Martis.
16. De alijs tribus extremæ noctis fulsionibus, circa stellam Martis

# NICOLAI COPERNICI

## REVLVTIONVM

LIBER PRIMVS.

Quòd mundus sit sphæricus. Cap. I.

“First of all, we must note that the universe is spherical”

17. De stella Martis.
18. De alijs tribus extremæ noctis fulsionibus, circa stellam Martis
19. De stella Martis.
20. De stella Veneris.
21. Quæ sit ratio dimetientium orbis terræ & Veneris.
22. De gemino Veneris motu.
23. De motu Veneris examinando.
24. De locis anomaliz Veneris.
25. De Mercurio.
26. De loco absidum summæ & infimæ Mercurij.
27. Quanta sit eccētrotres Mercurij, & quā habeat orbis symmetriam.
28. Cur digressiones Mercurij maiores appareant circa hexagoni latitudinis, eis quæ in perigæo contingunt.
29. Medij motus Mercurij examinatio.
30. De recentioribus Mercurij motibus obseruatis.
31. De præficiendis locis Mercurij.
32. De alia quadam ratione accessus ac recessus.
33. De tabulis prosthaphæreseon quinq; errantium stellarum.
34. Quomodo horum quinq; siderum loca numerentur in lōgitudine.
35. De stationibus & repedationibus quinq; errantium siderum.
36. Quomodo tēpora, loca, & circūferētiæ regressionū discernantur.

## LIBER SEXTVS.

1. De in latitudinem digressu quinq; errantiū expositio generalis.
2. Hypotheses circularum, quibus hæ stellæ in latitudinem feruntur.
3. Quanta sit inclinatio orbium Saturni, Iouis, & Martis.
4. De cæteris quibuslibet, & in uniuersum latitudinibus exponendis horum trium siderum.
5. De Veneris & Mercurij latitudinibus.
6. De secundo in latitudinem transitu Venetis & Mercurij secundū obliquitatem suorum orbium in apogæo & perigæo. (curij.
7. Quales sunt anguli obliuationū utriusq; sideris Veneris & Mercurij.
8. De tertia latitudinis specie Veneris & Mercurij, quam uocant De uiationem.
9. De numeratione latitudinum quinq; errantium.

FINIS.

NICOLAI



ma perfectissima sit omnium, nona mensura compagine, tota integra: siue quòd ipsa capacissima sit figurarum, quæ comprehensurum omnia, & conseruaturum maxime decet: siue etiam quòd absolutissimæ quæq; mundi partes, Solem dico, Lunam & stellas, tali forma conspiciantur: siue quòd hac uniuersa appetant terminari, quod in aquæ guttis cæterisq; liquidis corporibus apparet, dum per se terminari cupiunt. Quo minus talem formam cœlestibus corporibus attributam quisquam dubitauerit.

Quòd terra quoq; sphærica sit. Cap. II.



Erram quoq; globosam esse, quoniam ab omni parte centro suo innititur. Tamen si absolutus orbis non statim uideatur, in tanta montium excellitate, descensuq; uallium, quæ tamen uniuersam terræ rotunditatem minime uariant. Quod ita manifestum est. Nam ad Septentrionem undequaq; comitantibus, uertex ille diurnæ reuolutionis paulatim attollitur, altero tantundem ex aduerso subeunte, pluresq; stellæ circum Septentriones uidentur non occidere, & in Austro quædam amplius non oriri. Ita Canopum non cernit Italia, Ægypto patentem, Et Italia postremam fluminis stellam uidet, quam regio nostra plagæ rigentioris ignorat. E contrario in Austrum transeuntibus attolluntur illa, residentibus ijs, quæ nobis excelsa sunt. Interea & ipsæ polorum inclinationes ad emensa terrarum spacia eandem ubiq; rationem habent, quod

a in

# On knowing

As we know, there are known  
knowns. There are things we  
know we know. We also know  
there are known unknowns.  
That is to say, we know there  
are some things we do not  
know. But there are also  
unknown unknowns, the ones  
we don't know we don't know.

*Donald Rumsfeld*  
*Feb. 12, 2002*  
*Department of Defense*  
*news briefing*



**He left out the most important one!**

**"It ain't so much the things we don't know that get us in trouble. It's the things we know that ain't so."**



Artemus Ward  
American writer  
1834-1867

- Beware the known unknowns!
- Not everything “self-evident” is true!

# **Copernicus held these truths to be self evident:**

- **Uniform Circular Motions**

“First of all, we must note that the universe is spherical”  
*Copernicus*

“The axiom of astronomy: Celestial motions are circular and uniform or composed of circular and uniform parts.”  
*Erasmus Reinhold*

- **Motions centered on the sun**

It hardly matters to me whether he [Copernicus] claims that Earth moves or that it is immobile, so long as we get an absolutely exact knowledge of the movements of the stars and the periods of their movements, so long as both are reduced to altogether exact calculation

-- Gemma Frisius (astronomer)

... the subject of Copernicus is astronomy, whose most distinctive methodology is to use false and imaginary principles for saving appearances.

-- from Church decree placing  
*De Revolutionibus* on the Index

# ***DESIDERATA***

- 1) Common Sense**
- 2) Simple**
- 3) Reproduce observations**



...the arguments against the movement of Earth are very plausible ... the experiences that overtly contradict the annual movement [of Earth] are so great, that there is no limit to my astonishment when I reflect that Copernicus was able to make reason so conquer sense, that in defiance of the latter, the former became mistress of his belief.

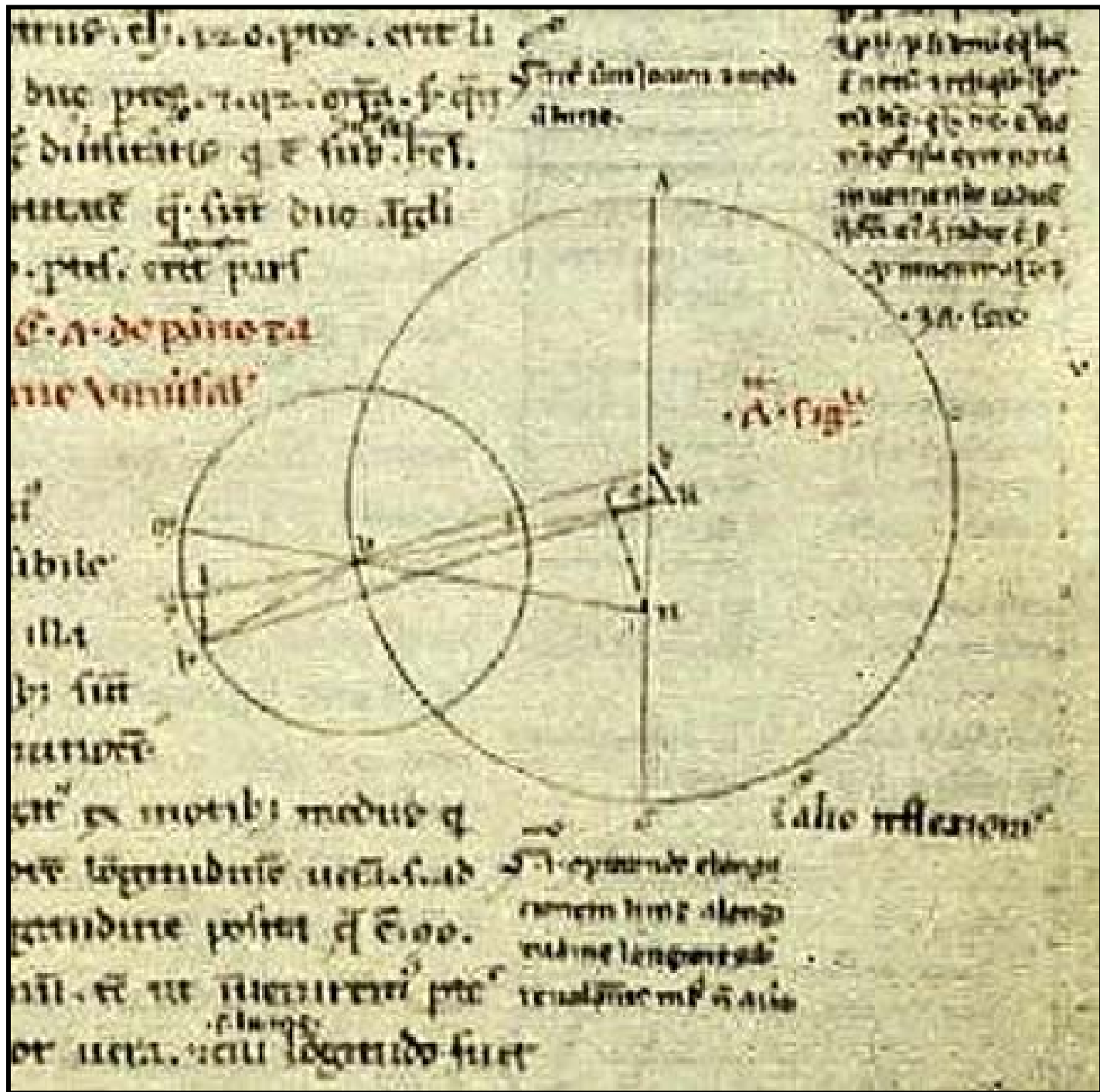
Galileo, 1632

*Dialogue Concerning the Two Chief World Systems*

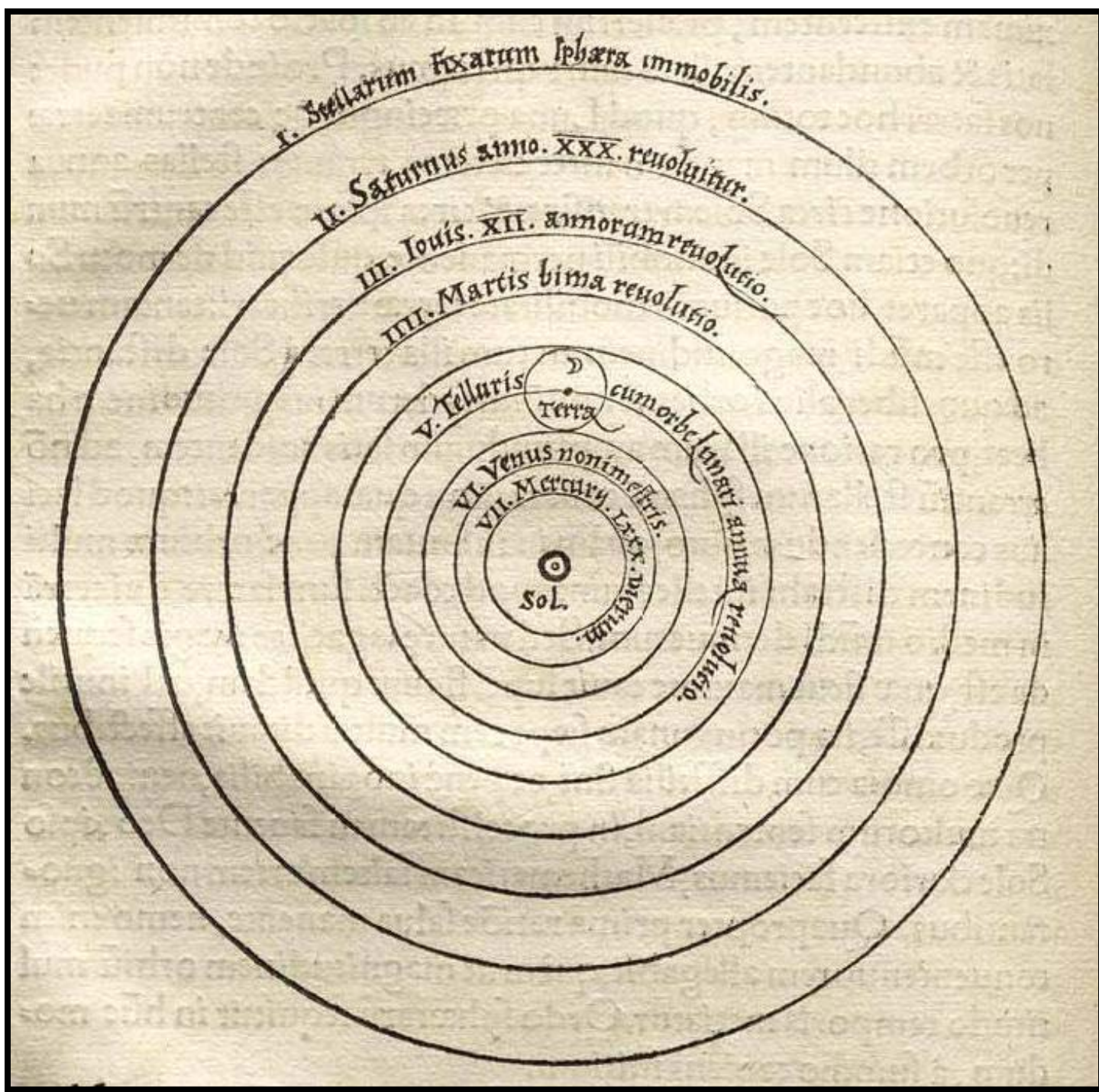
# ***DESIDERATA***

- 1) Common Sense**
- 2) Simple**
- 3) Reproduce observations**

# Ptolemaic System From *The Almagest*

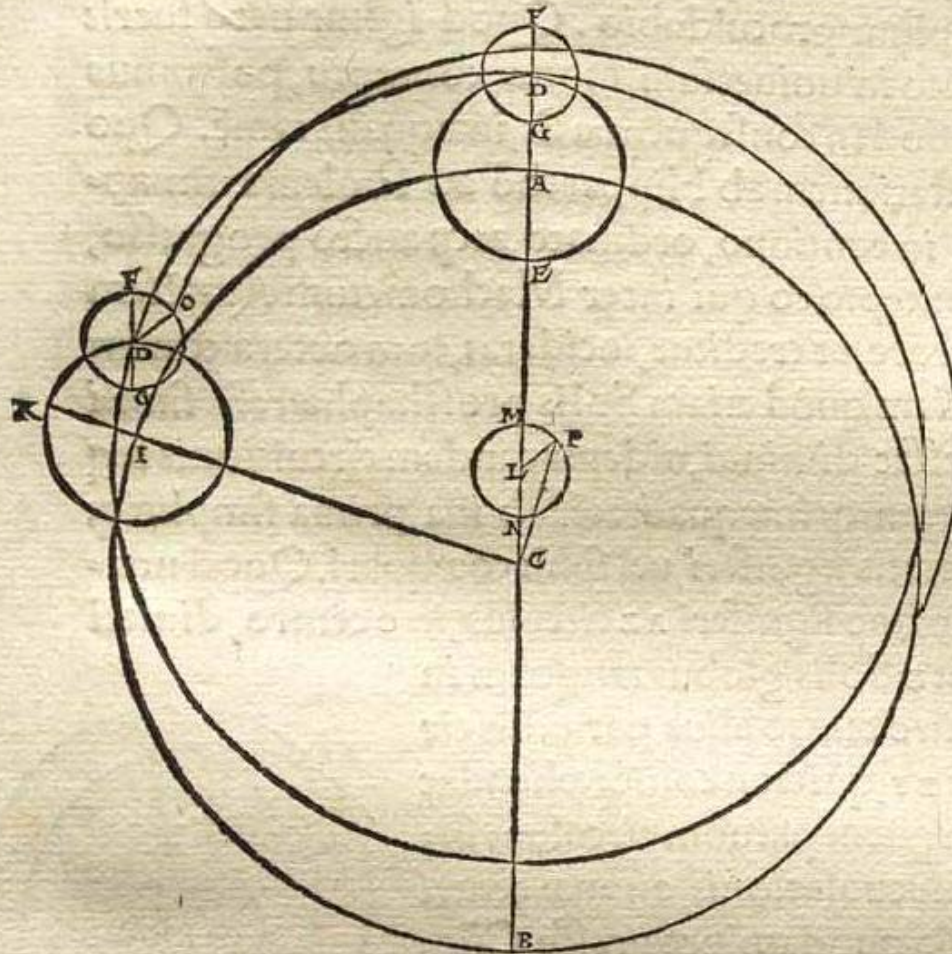


# From Book I of *De Revolutionibus*



# From Book III of De Revolutionibus

quoque epicyclum hoc modo. Sit mundo ac Soli homocentrus  
AB, & ACB diameter, in qua summa abscis contingat. Et facta in  
a centro epicyclus describatur DE, ac rursus in D centro epicycli-  
um FG, in quo terra uersetur, omniaque in eodem plano zodiaci.



Sitque epicycli  
primi motus  
in succedentia,  
ac annuus fe-  
rè, secūdi quod  
hoc est D, simi-  
liter annuus,  
sed in præce-  
dentia, ambo-  
rumque ad AC  
lineam pares  
sint reuolutio-  
nes. Rursus  
cētrum terræ  
ex F in præce-  
dentia addat  
parumper ip-  
si D. Ex hoc  
manifestū est

quod cum terra fuerit in F, maximum efficiet Solis apogeu-  
m, in G minimum: in medijs autem circumferentijs ipsius F G epi-  
cyclij faciet ipsum apogeu- m præcedere uel sequi auctum dimi-

# ***What Copernicus “Knew”***

**“First of all, we must note that the universe is spherical.”**

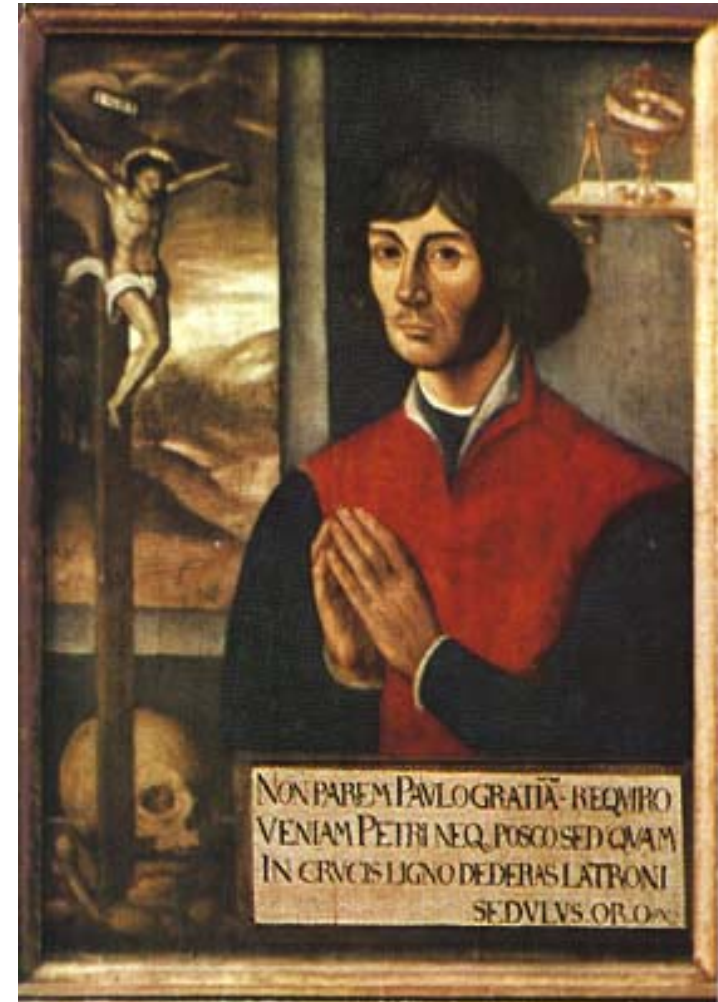
***Elliptical orbits!***

**Motions are centered on the sun**

***Sun at a focus!***

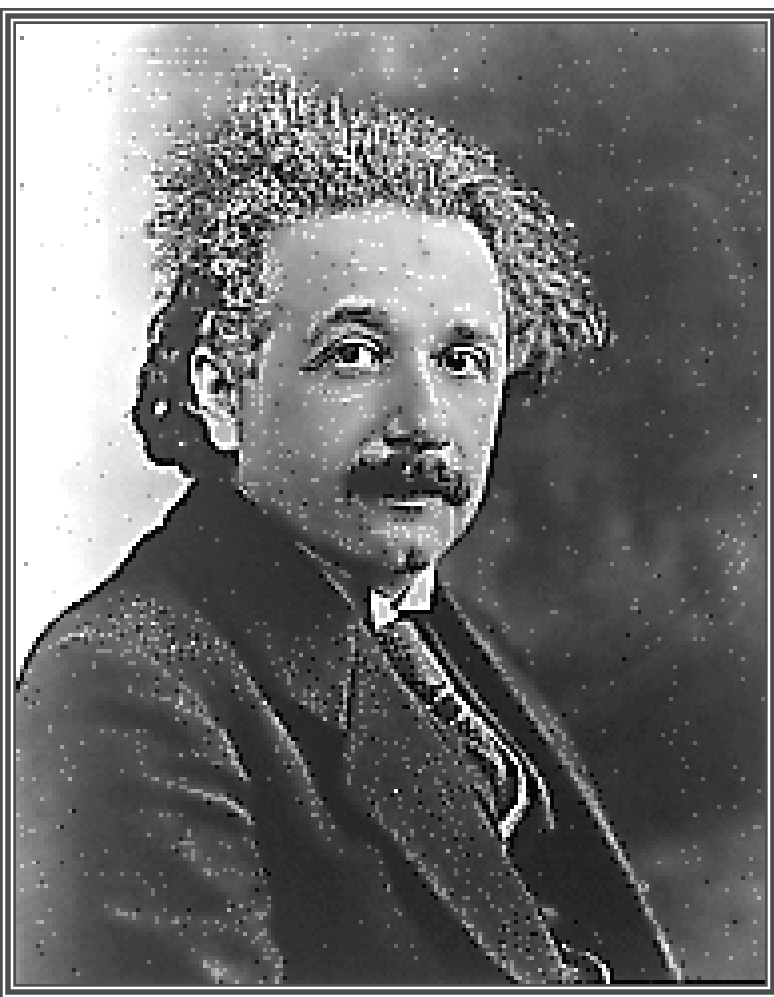
**Uniform velocities**

***Equal areas in equal times!***



# ***DESIDERATA***

- 1) Common Sense**
- 2) Simple**
- 3) Reproduce observations**

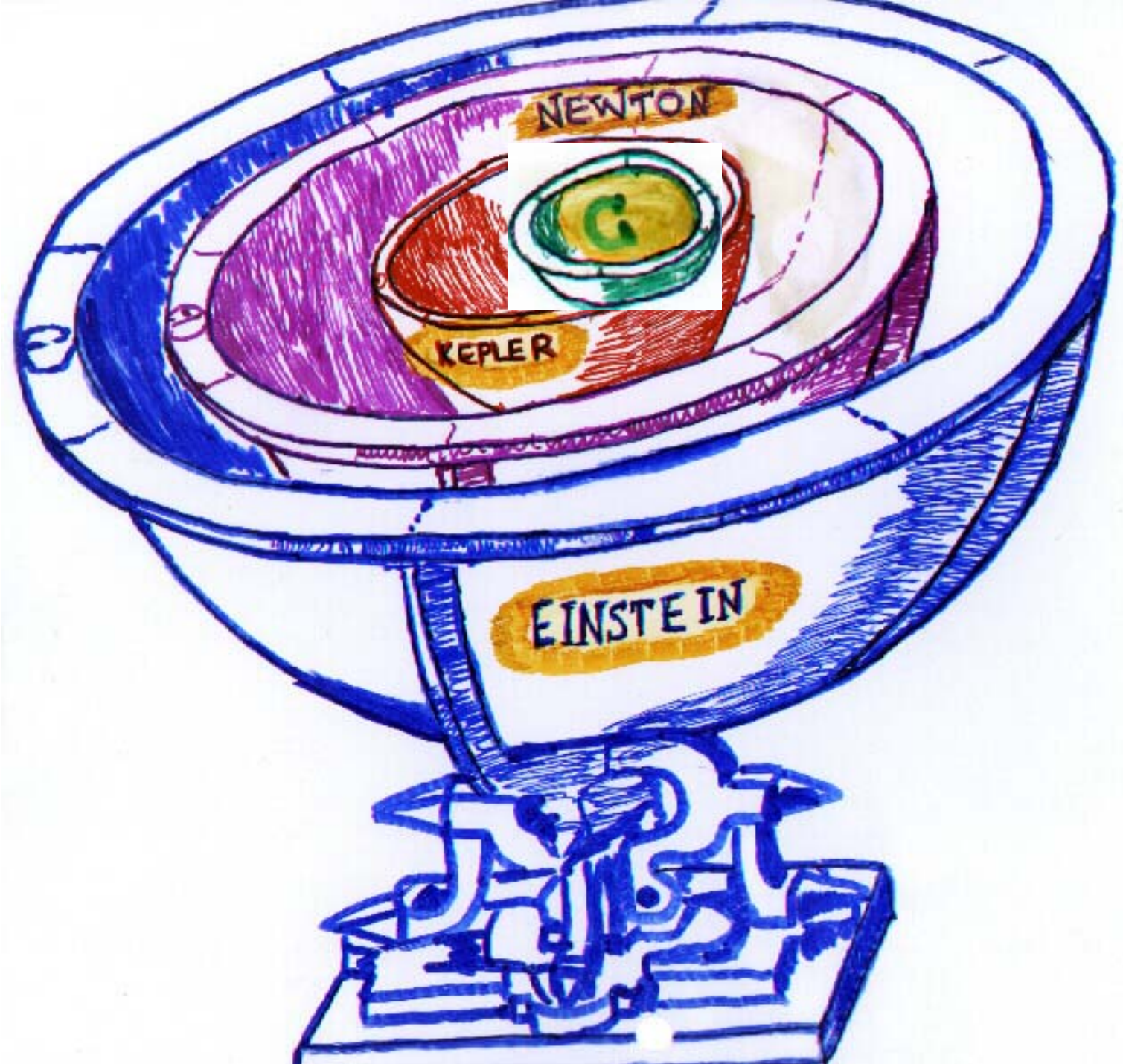


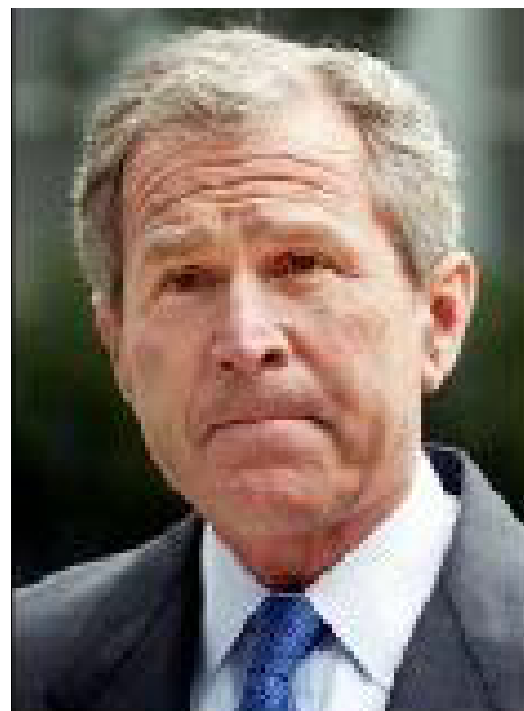
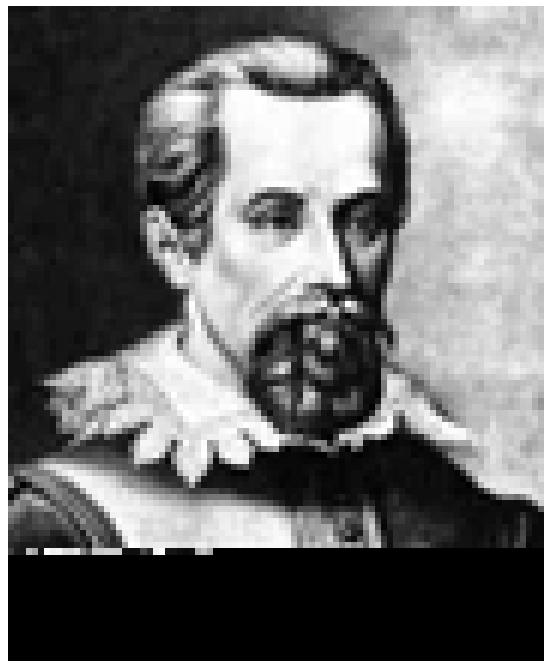
In advocating and fighting for the Copernican theory, Galileo was not only motivated by a striving to simplify the representation of the celestial motions. His aim was to substitute for a petrified and barren system of ideas the unbiased and strenuous quest for a deeper and more consistent comprehension of the physical and astronomical facts.

Albert Einstein

*in the foreword to the Drake translation of Galileo's Dialogues*







Johannes Kepler:  
Kepler, Keppler, Khepler, Kheppler, and Keplerus

Michelangelo Merisi:  
Merisi, Amerigi, Merigi, Merici, Morisi, Merisio, Morigi,  
Morisimus, Amarigi, Marigi, Marisi, Narigi, Moriggia,  
Marresi, and Amerighi

# Parking Available For:

- NBC Tower
- 401 N. Michigan
- Sheraton Hotel
- Univ. of Chicago
- Navy Pier
- North Pier Terminal
- Jerry Springer



...at the age of 4, I nearly died of smallpox.

... my hands were badly crippled.

... during the age of 14 & 15 I suffered continuously from skin ailments, severe sores, scabs, putrid wounds on my feet.

... on the middle finger of my right hand I had a worm.

... I had a huge sore on my left hand.

... when 16 I nearly died of a fever.

... at 19 I suffered from headaches and disturbances of my limbs.

... I continuously suffered from the mange and the dry disease.

... at the age of 20 I suffered a disturbance of the body and mind.

...once, at the urging of my wife, I took a bath.

... it's heat constricted my bowles and nearly killed me.

... I believe I am one of those people whose gall bladder has a direct opening into the stomach. Such people are short-lived as a rule.

...I hated Kolinus.

... Braunbaum was my enemy.

... I willingly incurred the hatred of Seiffer.

... Ortholphus hated me as I hated Kolinus.

... Kleberus hated me as a rival.

... my talent made Rebstock hate me.

... Husalius opposed my progress.

... Jaeger betrayed me.

... at the age of 21 I gained knowledge of woman. I achieved this with the greatest possible difficulty, experiencing the most acute pains of the bladder.

Barbara Muehleck Kepler:

“... simple of mind and fat of body, with a stupid, sulking, lonely, melancholy disposition.”

...that man has in every way a dog-like nature.

... his appearance is that of a little lapdog.

... his appetites are like a dog; he likes gnawing on bones and dry crusts of bread.

... like a dog he drinks little and is content with the simplest foods.

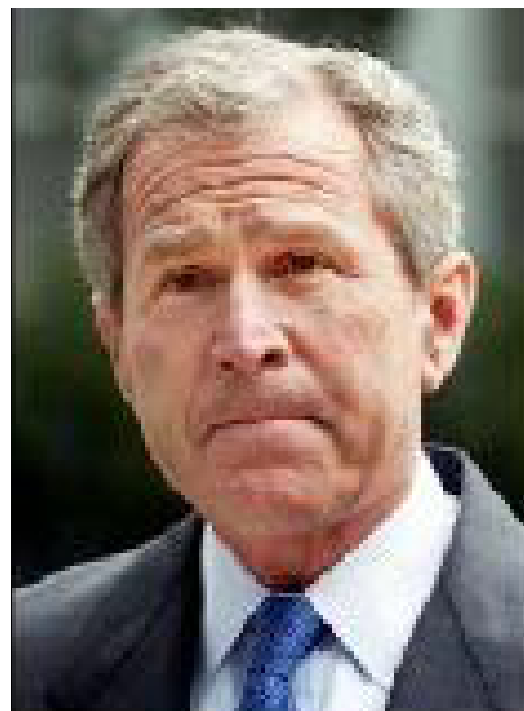
... he happily greets visitors like a dog.

... when something is snatched from him he sits up and growls.

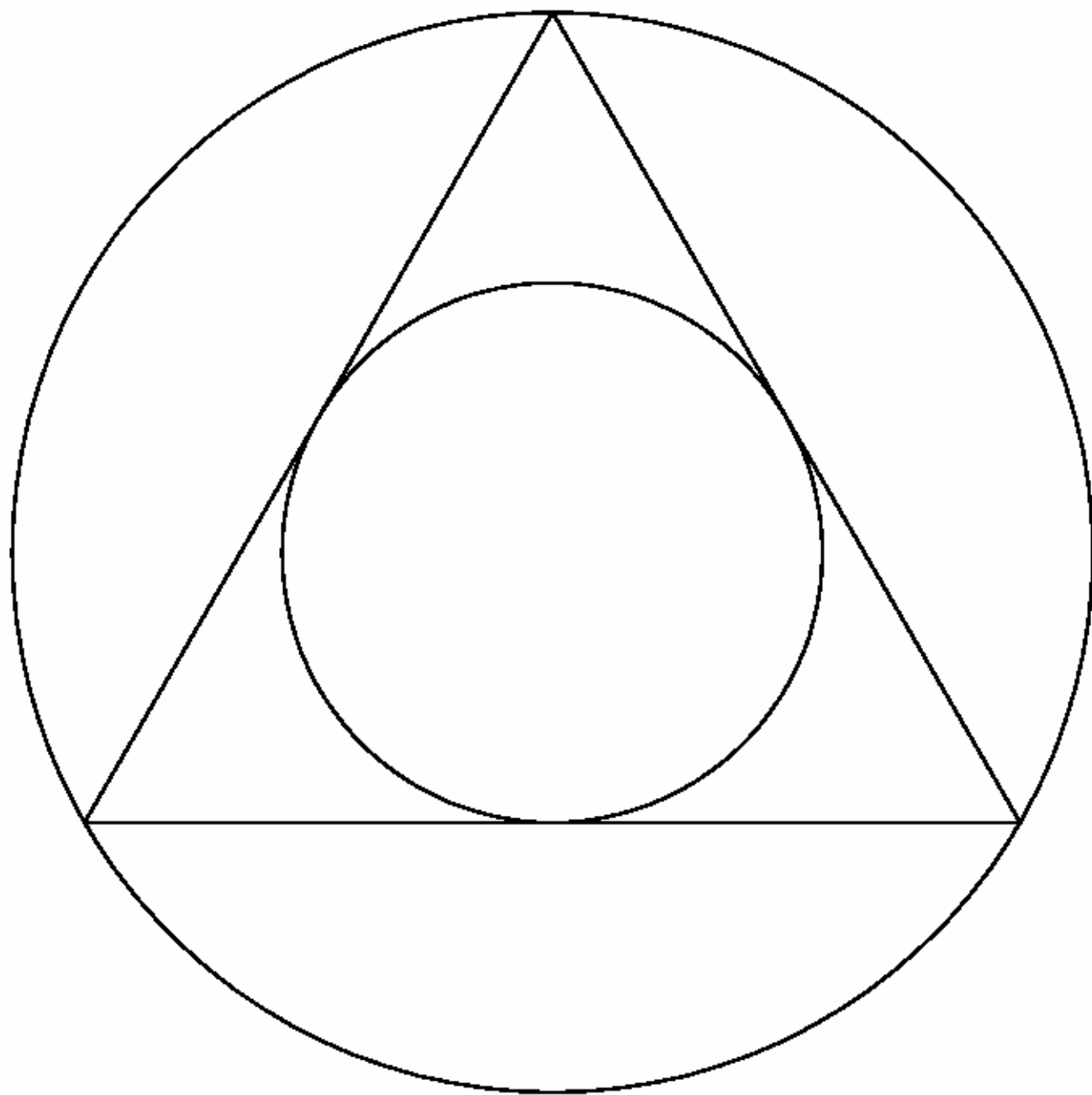
... he barks at wrong doers

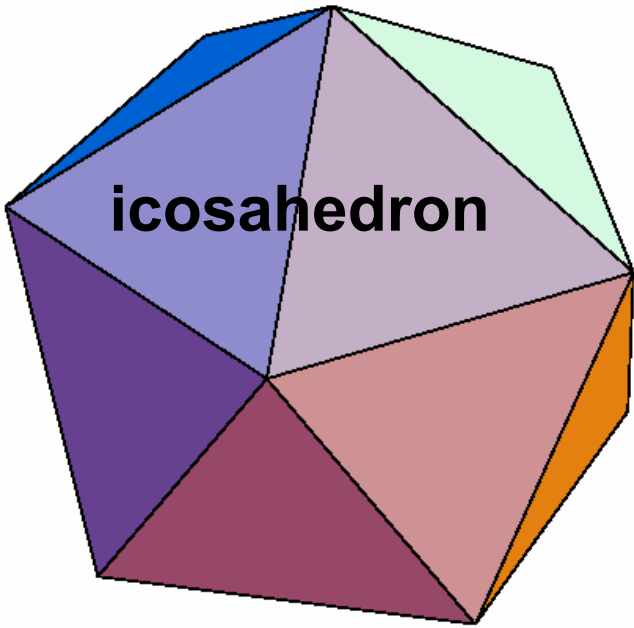
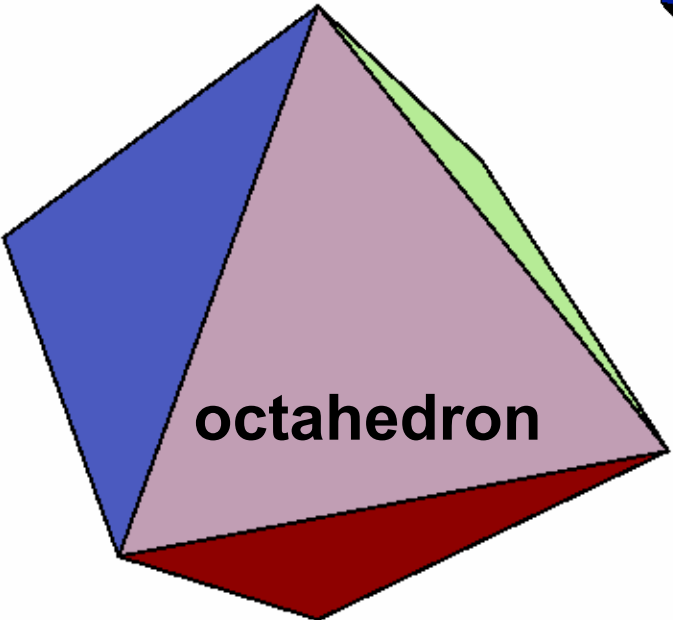
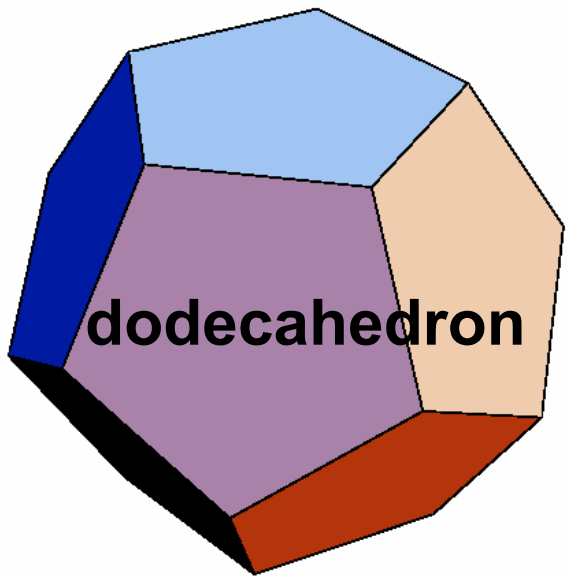
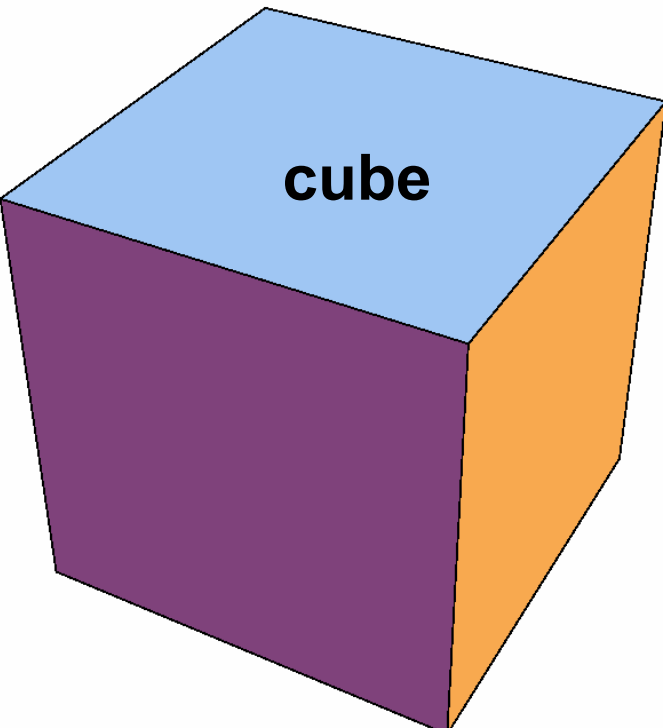
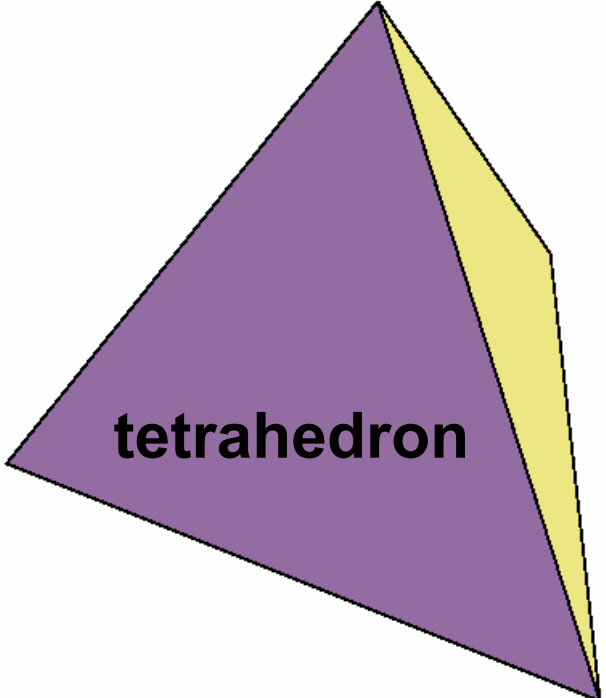
... he is malicious and bites people with sarcasms.

... he has a dog-like horrors of baths

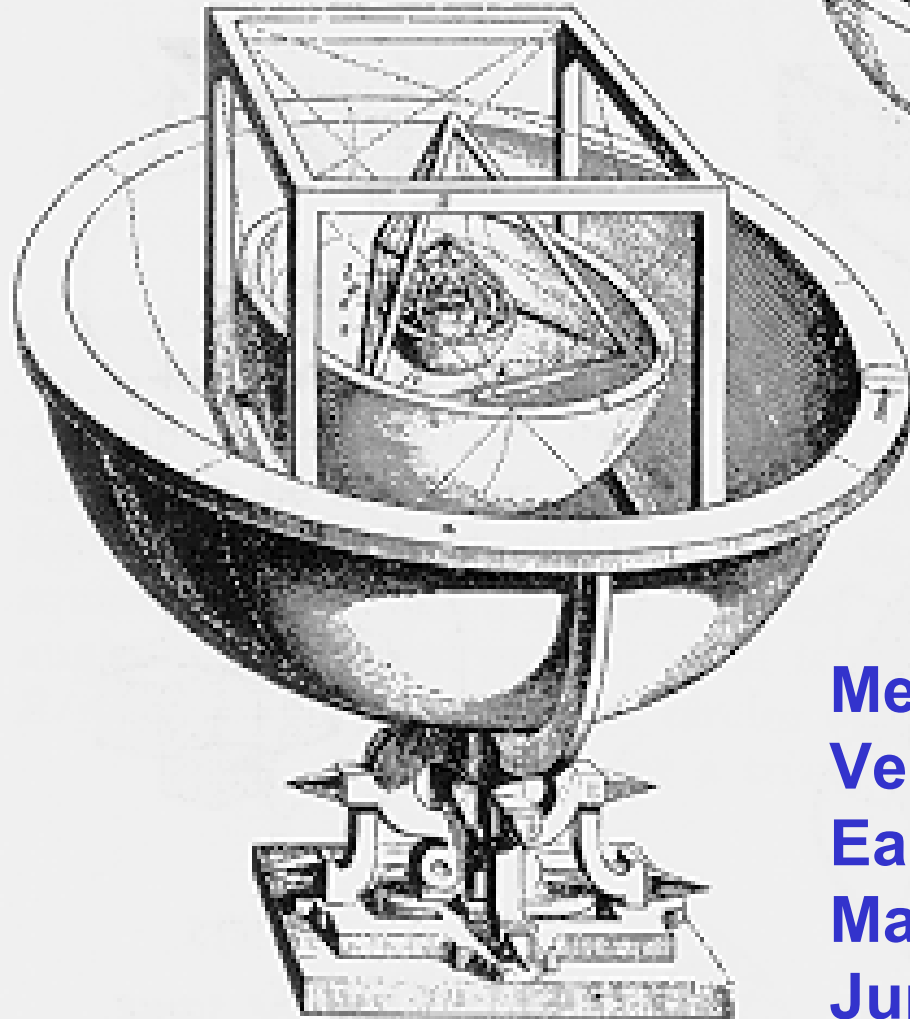








# Mysterium Cosmographicum



Mercury – octahedron - Venus  
Venus – icosahedron – Earth  
Earth – dodecahedron – Mars  
Mars – tetrahedron – Jupiter  
Jupiter – cube - Saturn

<b>Planets and Polyhedra</b>	<b>from Polyhedra</b>	<b>from Copernicus</b>
<b>Saturn-cube-Jupiter</b>	<b>577</b>	<b>635</b>
<b>Jupiter-tetra-Mars</b>	<b>333</b>	<b>333</b>
<b>Mars-dodeca-Earth</b>	<b>795</b>	<b>795</b>
<b>Earth-icosa-Venus</b>	<b>795</b>	<b>794</b>
<b>Venus-octa-Mercury</b>	<b>707</b>	<b>723</b>

# Nicolai Copernici, *Revolutions* Book One

(Edward Rosen translation)

## The Universe is Spherical, Chapter 1

Quod mundus sit sphaericus. Cap. i.

First of all, we must note that the universe is spherical. The reason is either that, of all forms, the sphere is the most perfect, ...; or that it is the most capacious\* of figures, best suited to enclose and retain all things; ... Hence, no one will question the attribution of this form to the divine bodies.

## The Earth Too is Spherical. Chapter 2

Quod terra quoque sphaerica sit. Cap. ii.

**T**erram quoque globosam esse, quoniam ab omni parte centro suo innititur. Tamen si absolutus orbis non statim uideatur, in tanta montium excelsitate, descen-

\*capacious: able to contain much.

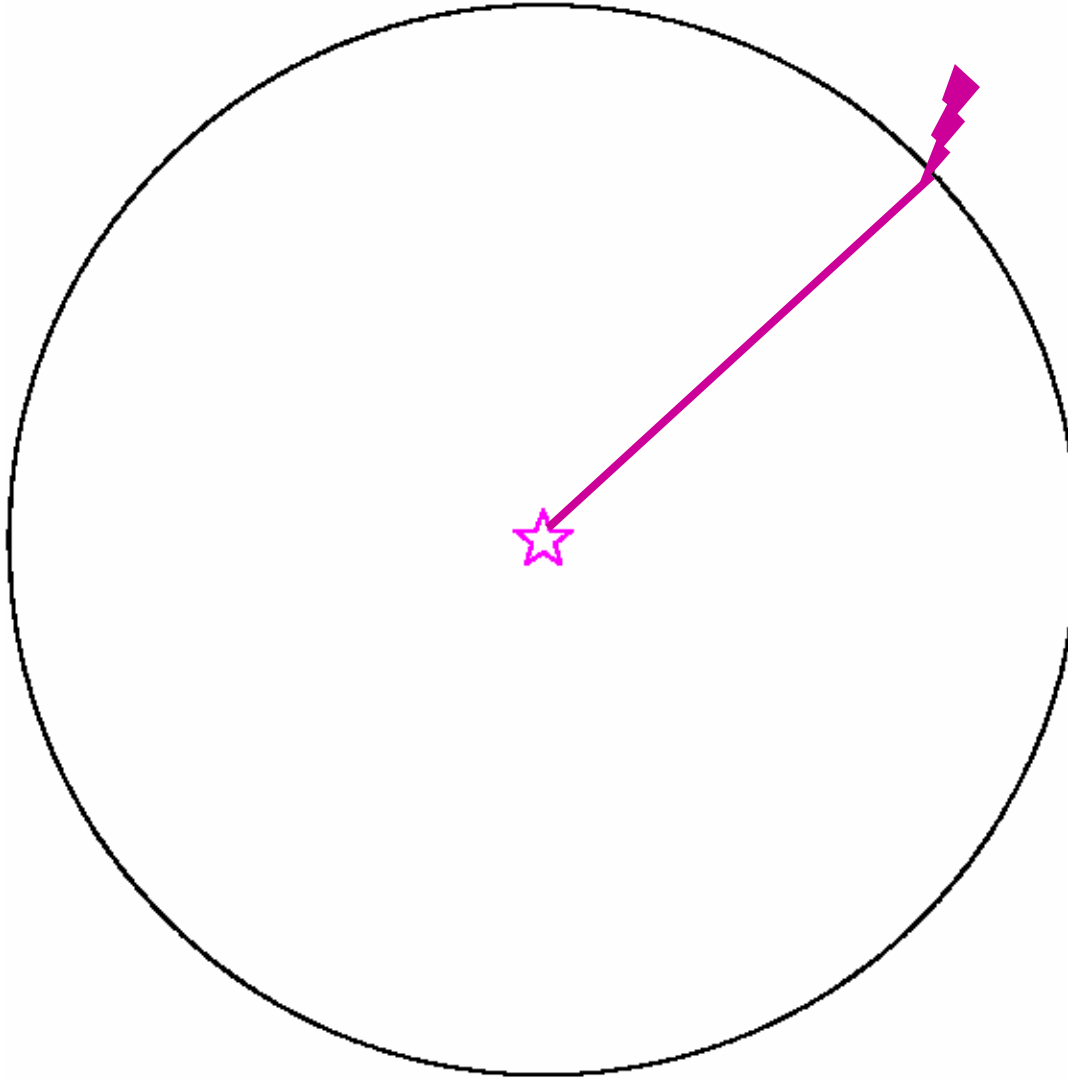
# Kepler's 1st Law



**circle**



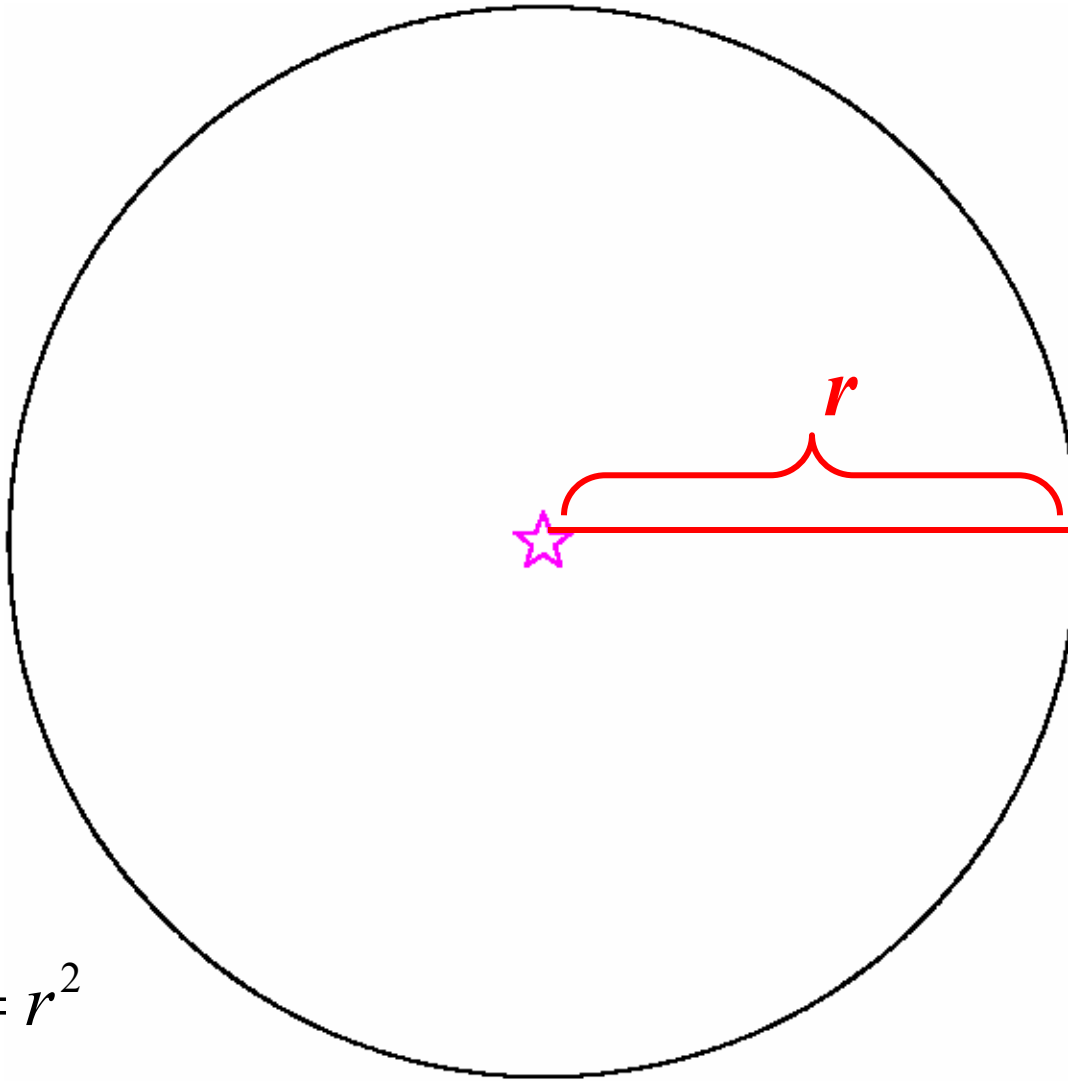
**center**



**circle**



**center**



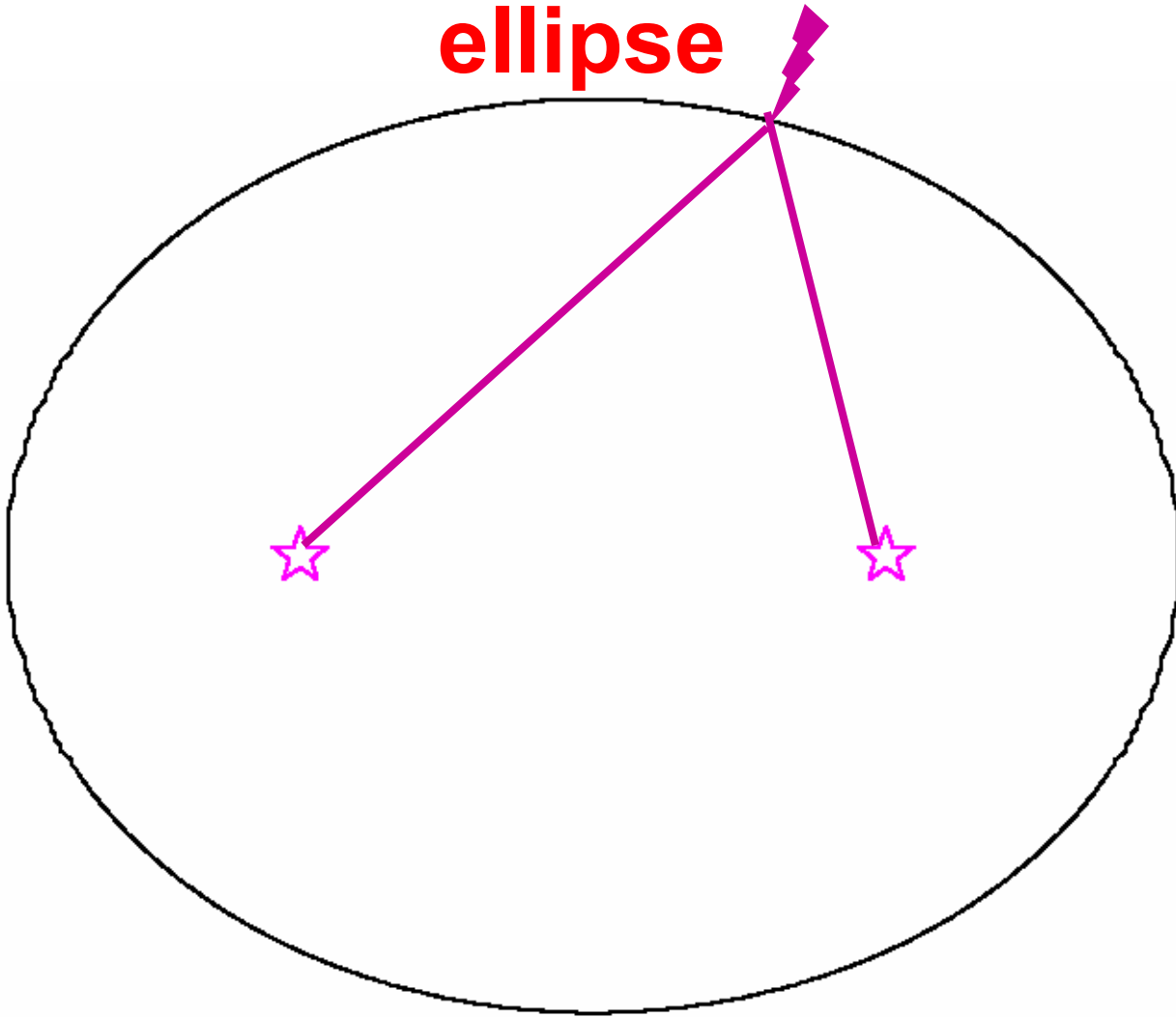
$$x^2 + y^2 = r^2$$

$$\frac{x^2}{r^2} + \frac{y^2}{r^2} = 1 \quad r^2 > 0$$

**ellipse**

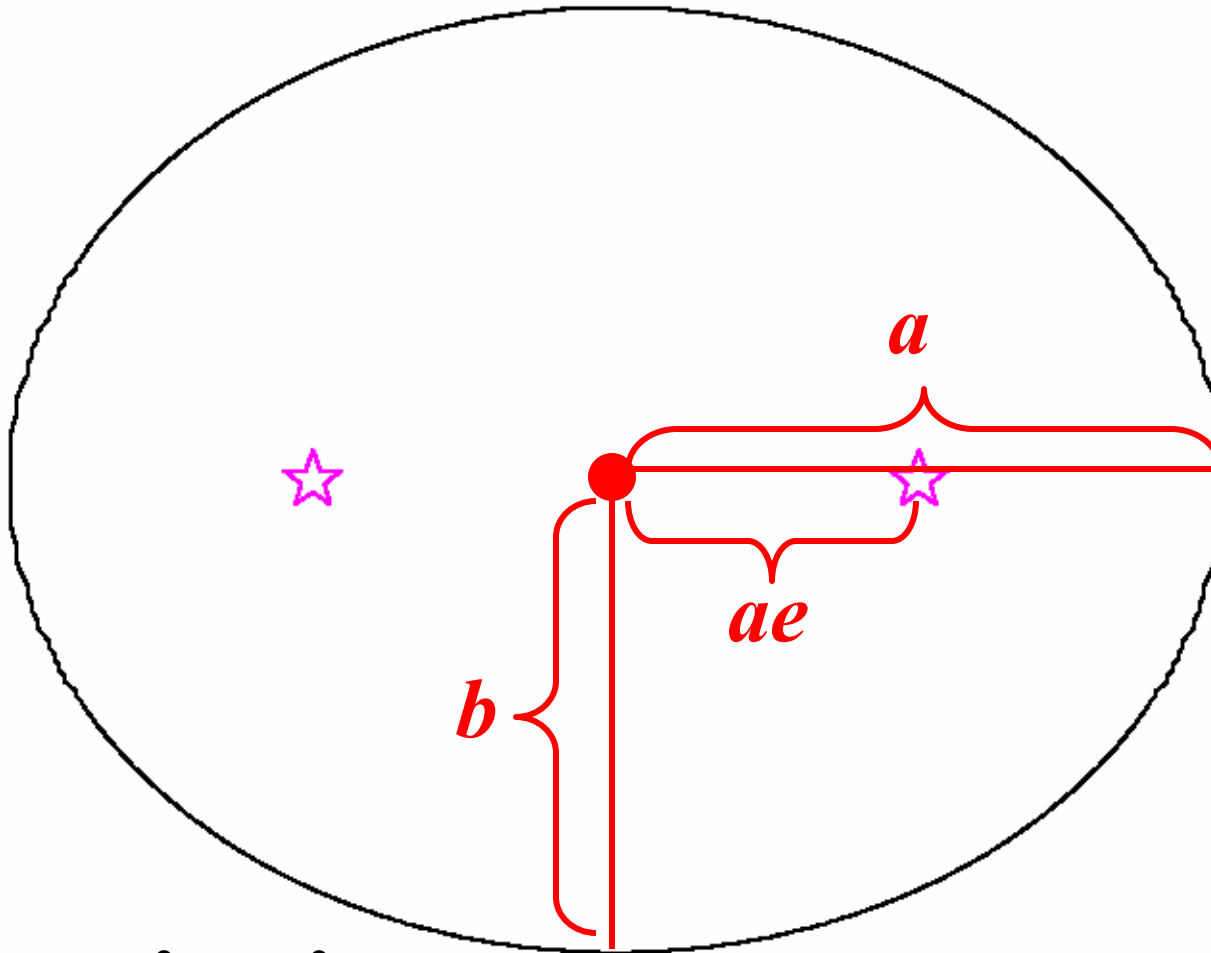


**focus**



# ellipse

☆  
focus

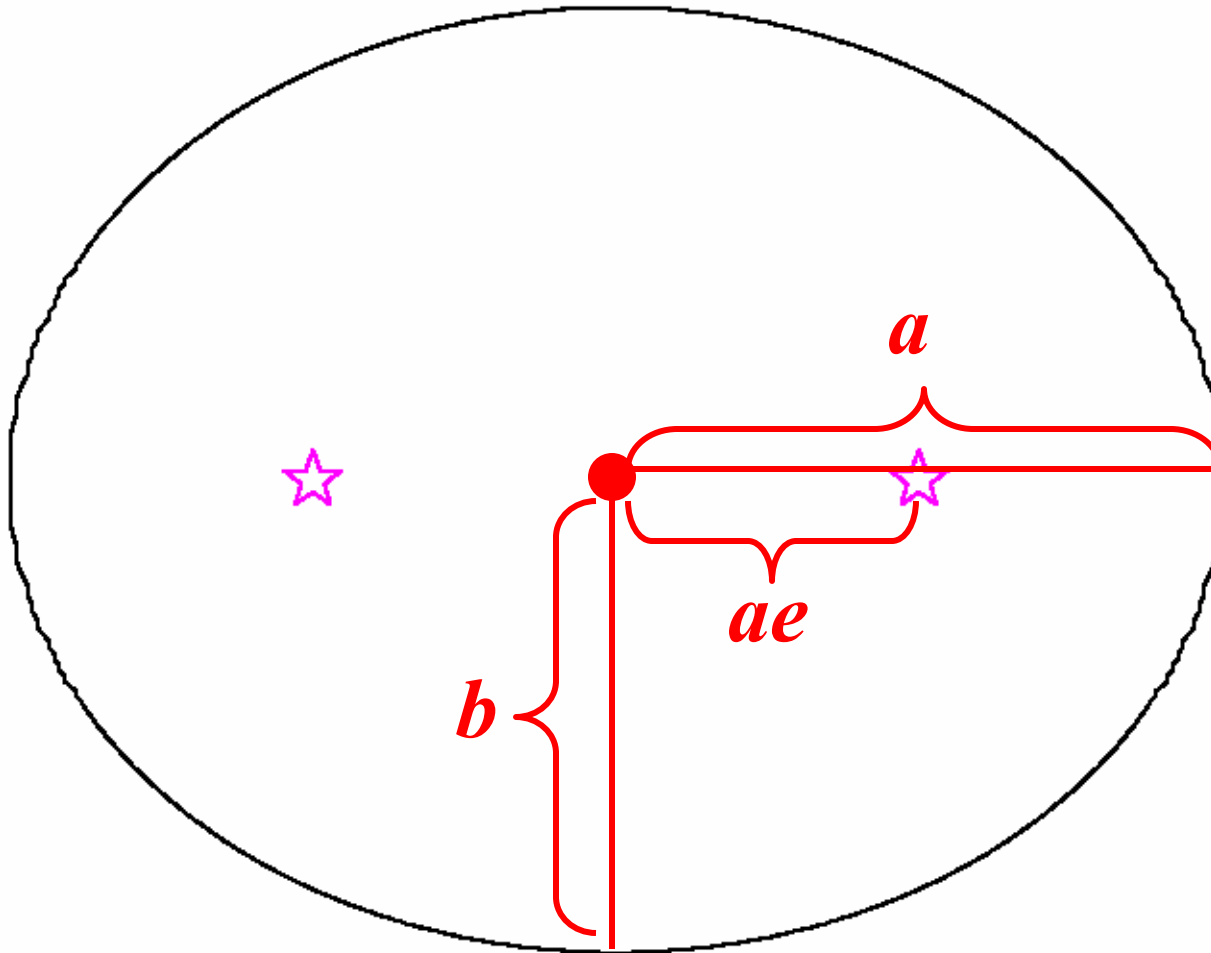


$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1 \quad a > b > 0$$

$$\text{eccentricity } e = \sqrt{1 - b^2 / a^2} = 0.5$$

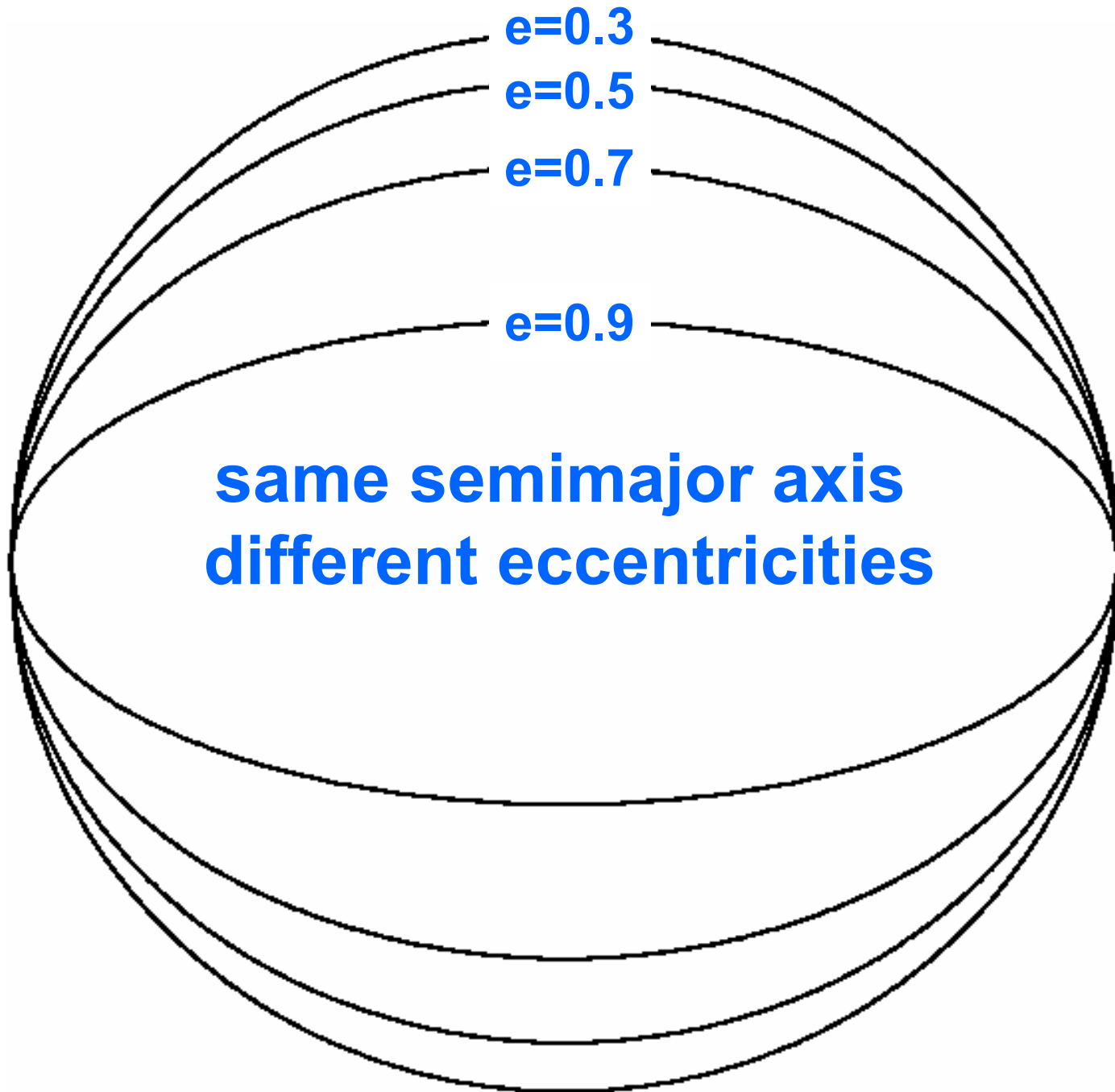
# ellipse

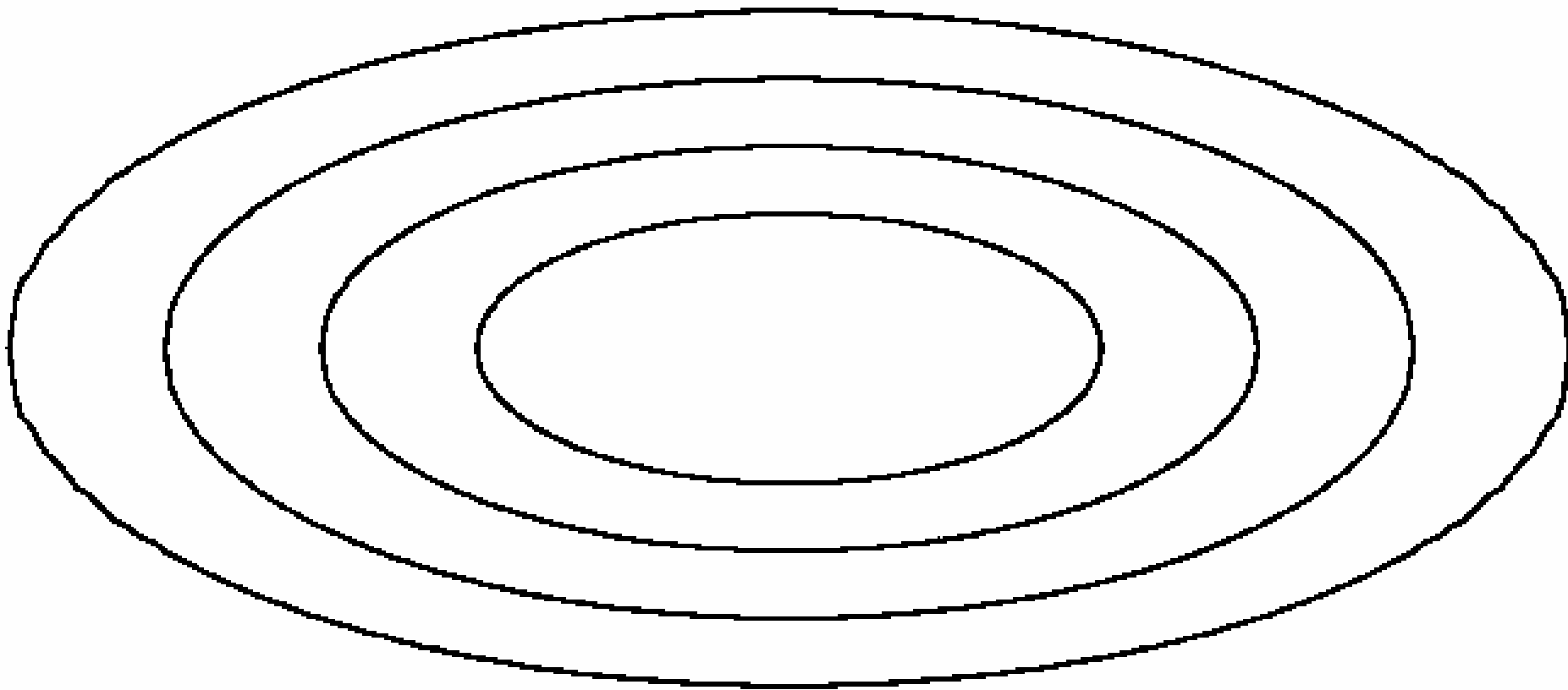
☆  
focus



$$\text{eccentricity } e = \sqrt{1 - b^2/a^2} = 0.5$$

$$b/a = \sqrt{1 - e^2} \simeq 1 - \frac{1}{2}e^2 \quad \text{for } e \text{ small}$$

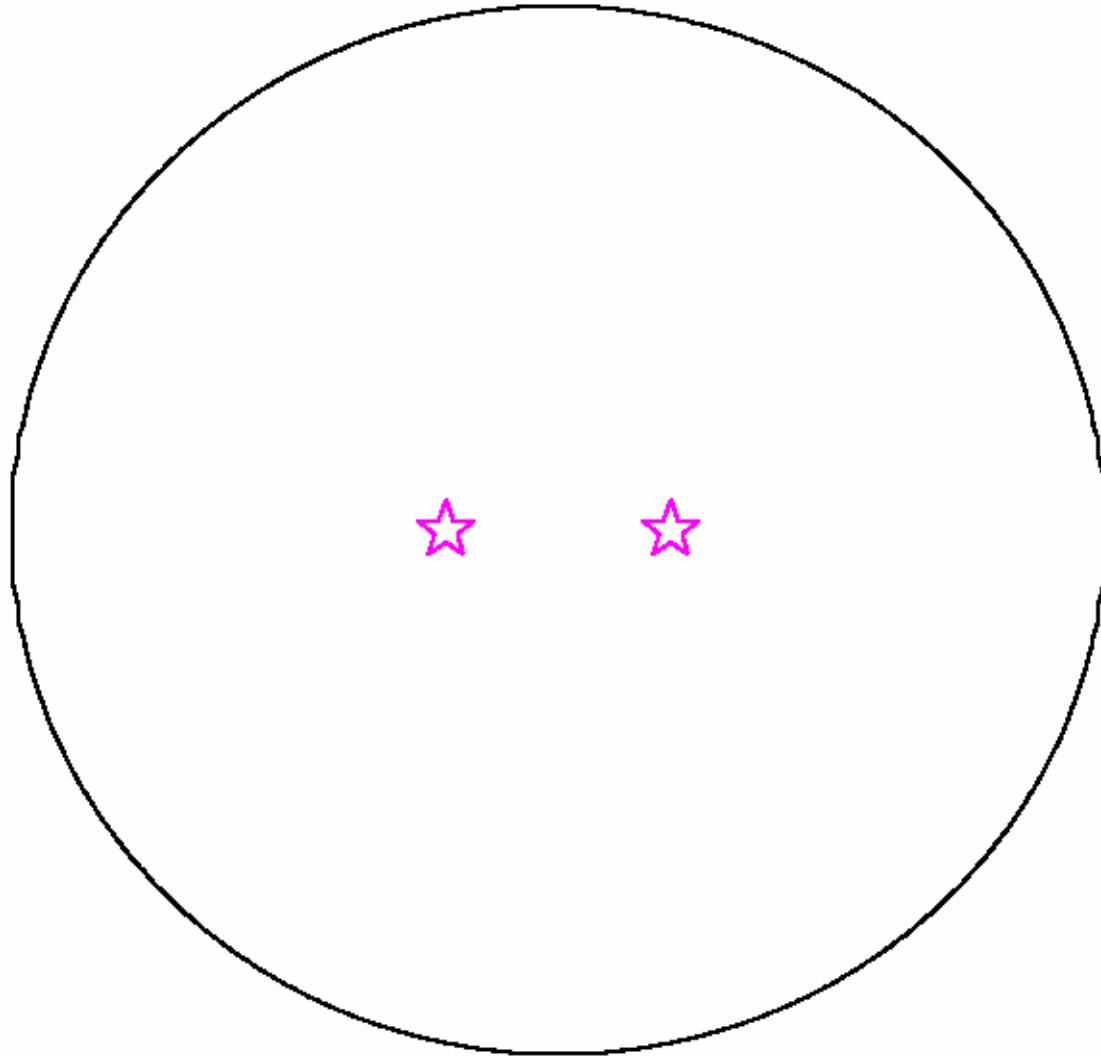




**same eccentricity**

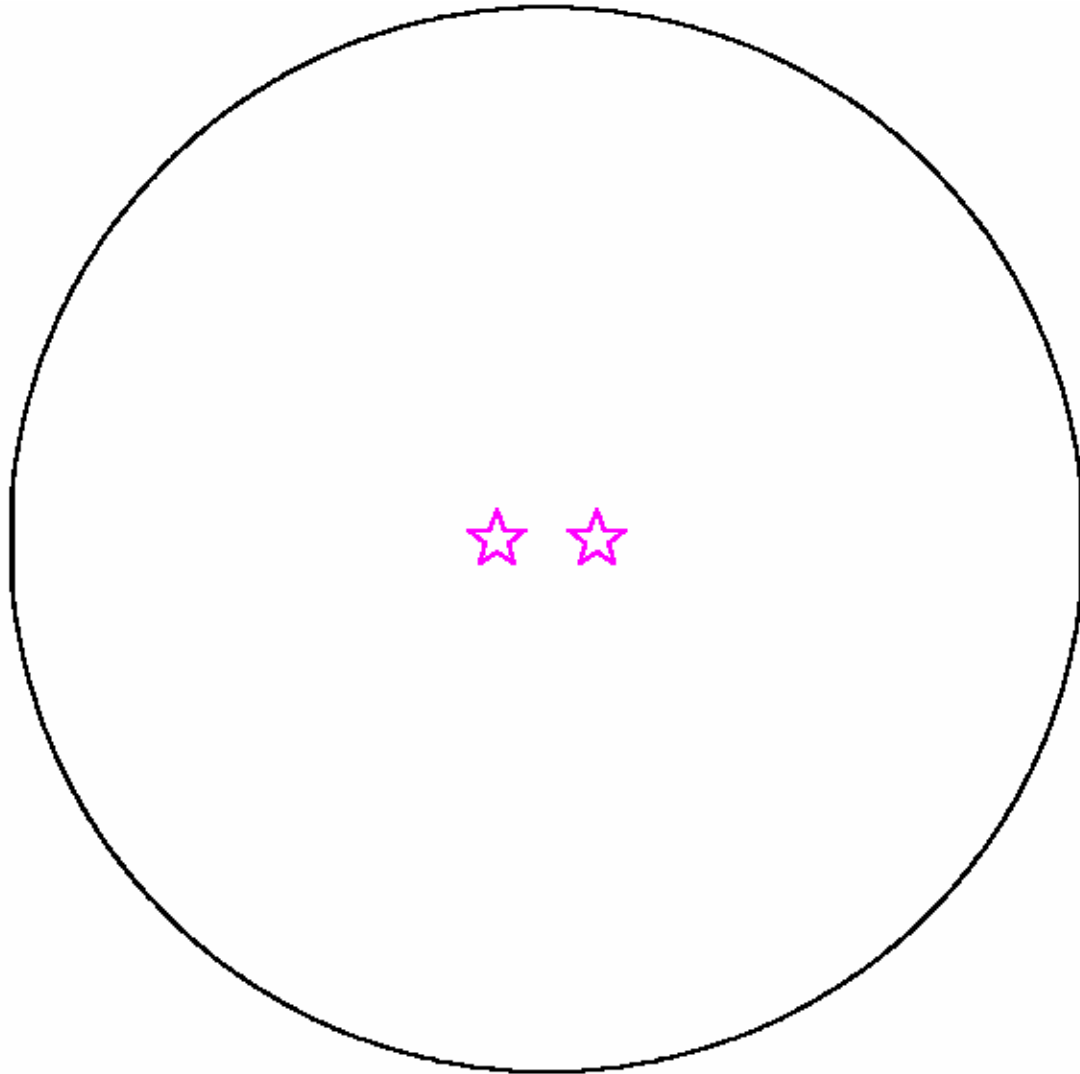
**different semimajor axis**

# Mercury

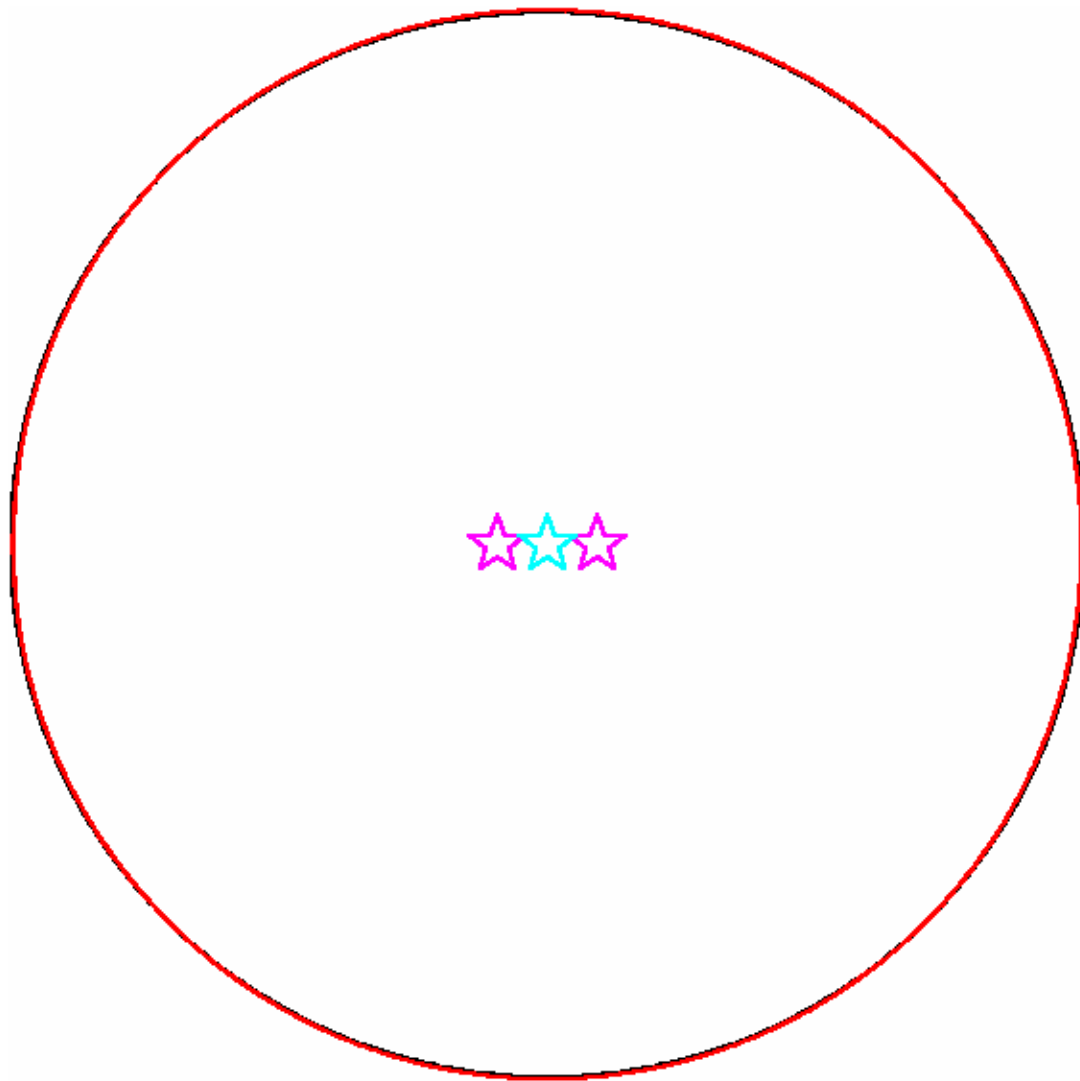


eccentricity = 0.2

# Mars



$\text{eccentricity} = 0.09$



○ **ellipse with eccentricity of Mars**    **circle with same area** ○

# The Ptolemaic Epicycle

